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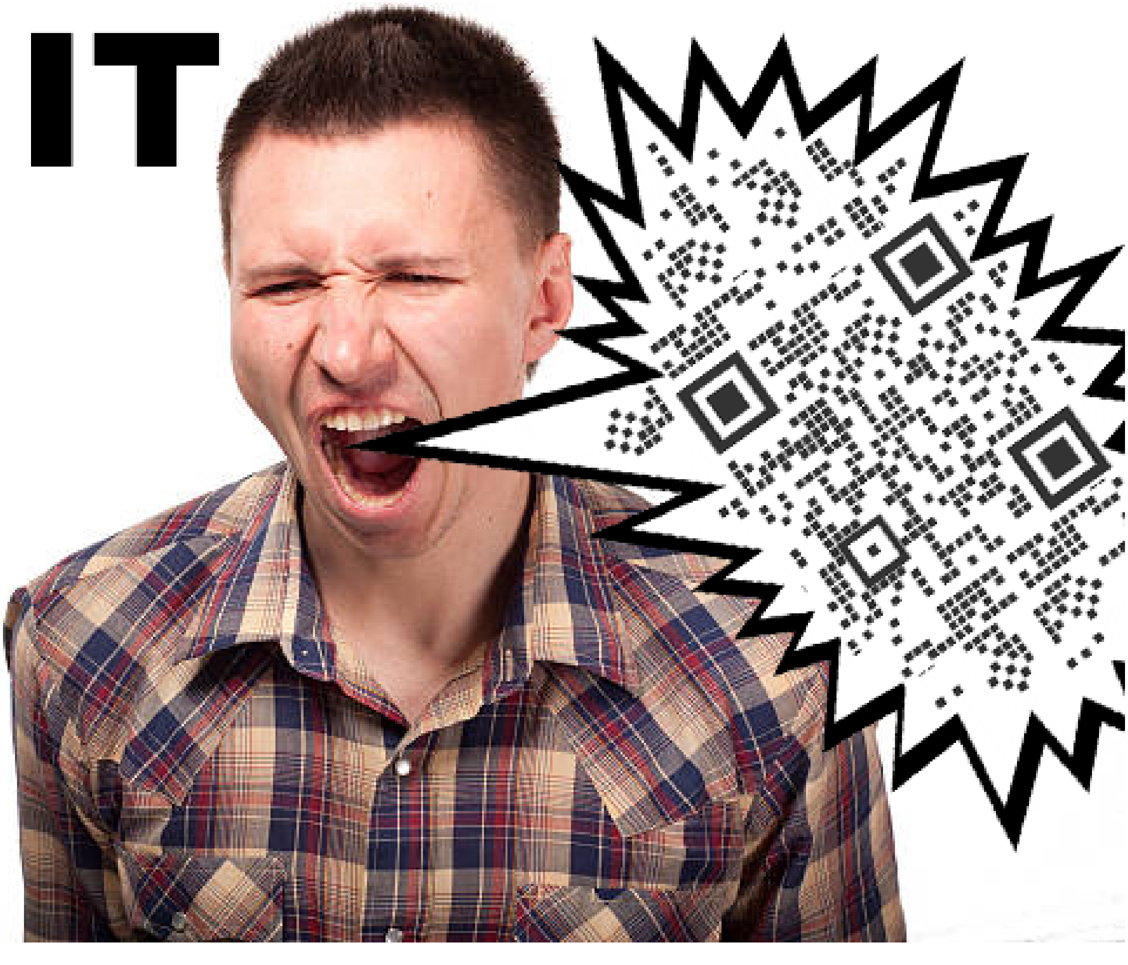

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ERRATA

Page 33, fourth line of legend inside Figure 6: *inside* should read *outside.*

Page 72, line 11: *52.5 per cent* should read *47.5 per cent.*

Page 123, Figure 25: *Milercertium campanula* should read *Melicertum campanula.*

Page 130, line 7 under the heading "Annulata and Vermes": *Tomopteros* should read *Tomopterus.*

Page 155, Figure 55: The symbol for *Palæmonetes vulgaris* should be — — — — instead of ——•——.

VARIATION IN THE MAXIMUM DEPTH AT WHICH FISH CAN LIVE DURING SUMMER IN A MODERATELY DEEP LAKE WITH A THERMOCLINE

⁂

By FRANK SMITH
Professor of Zoology, University of Illinois

⁂

Contribution from the University of Michigan Biological Station and the Zoological Laboratory of the University of Illinois

⁂

During several summer sessions the writer served on the staff of the University of Michigan Biological Station, which is on the shore of Douglas Lake, about 17 miles south of the Straits of Mackinac. During the last few years of service he was responsible for instruction work, which included among other things a study of the habits and distribution of fishes in the lake. This led to a desire for a more precise knowledge concerning the vertical distribution of fish in places where the depth is sufficient to permit the establishment of a definite thermocline. During the latter part of the sessions of 1920 and 1921 attempts were made to determine the maximum depth at which fish could remain alive for any considerable length of time in such places and to ascertain what relation such maximum depth might have to the position of the thermocline and to the correlated oxygen and hydrogen-ion conditions. These attempts led to results sufficiently definite and interesting to make publication seem worth while. It became evident that one could predict, within 2 or 3 feet, what such maximum depth would be if furnished accurate data on the temperature, amount of dissolved oxygen, and the acidity conditions existing at levels having 2 or 3 foot intervals in the upper part of the thermocline. From the temperature data alone one could predict nearly as closely. Variations in the depth at which the thermocline is established are accompanied by similar variations in the maximum depth at which fish can remain alive.

Douglas Lake is approximately 4 miles in length, with its long axis extending in a northwest-southeast direction, and the average width is somewhat less than half as much. With the exception of about a half dozen small isolated areas, in which the water is 60 to 90 feet in depth, the water of the lake is too shallow to have a thermocline established. In the deep places or holes, as they are termed in station parlance, a thermocline is ordinarily present during July and August, when the station is in operation. The depth at which the thermocline is established varies considerably in the different holes and in any given one of them is subject to some fluctuation. The depth is apt to be greater in the latter part of the season, and long-continued, strong winds tend to depress the level of the upper part of the thermocline, if not of the entire stratum. For the observations described in this paper the two deep places nearest to the biological station were selected. One of them, which will be designated as Station A, is but a quarter of a mile away, and the other one, Station B, is about a mile from headquarters. Station A differs from the other stations in being partially sheltered by a high wooded bluff from the full force of the frequent, strong, northwest winds, while Station B is in a position to get the maximum effect of such winds. The thermocline at Station B was ordinarily several feet deeper than that of Station A.

The general plan of operations included the submergence of a series of wire cages attached at different levels to a rope which was suspended from a wooden buoy or float. The float was anchored in the desired situation, and the rope to which the cages were attached had a weight fastened to its lower end to keep the rope taut and maintain a constant depth for the cages. The cages were made of galvanized wire netting of about ½-inch mesh and were cubical in form, with each surface 1 foot square. Fish of several kinds were placed in each of the cages, and they were let down to the desired depths, where they remained until the next visit. Temperature readings and tests for the oxygen content and the hydrogen-ion condition at approximately the same levels as those at which the cages were placed made a part of the records. Subsequent visits at varying intervals of time were made for the purpose of examination of the condition of the caged fish, the removal of dead ones, and the addition of others. Not infrequently additional chemical and temperature examinations were made for comparison with the former ones.

For hearty cooperation in the provision of equipment and in the securing of necessary assistance thanks are due Dr. G. R. La Rue, the director of the biological station. Dr. P. S. Welch generously made the few chemical tests that were necessary the first season. In 1921 Dr. Minna Jewell, who was a member of the station corps of assistants, rendered most valuable service in making all of the chemical determinations and records. For this work she was particularly well fitted because of much previous experience in such chemical studies on this lake and elsewhere.

During the first season the observations were of a preliminary sort for the purpose of finding out whether the limiting depth is very definite, and whether the fish that were obtained in shallow water were suitable for the tests at greater depths. The results seemed to show that the lower limit of the body of water, which had the conditions necessary for sustaining the life of fish, was very sharply defined, and also made it apparent that the fish from shallow water were suitable for the tests.

The first test was made July 26, 1920, at Station A. Data of Doctor Welch, taken three days earlier, showed a thermocline between 45 and 53 feet, with plenty of oxygen at 45 feet. Two specimens of *Lepomis gibbosus* were placed in each of three minnow pails at depths of 40, 55, and 65 feet at 4.30 p. m. At 6.45 p. m. of the same day in each of the pails at the two lower levels one fish was dead and the other one nearly dead. Those in the pail at 40 feet were in good condition and were still living 24 hours later.

On July 28 at 10.40 a. m. yearling bullheads and suckers were placed in the pails at the same depths as before, and at 7 p. m. those in the two lower pails were dead, while those in the upper one were in good condition, and most of the latter were still living 24 hours later.

At Station B, August 3 at 10.35 a. m., four wire cages were placed at 40, 49, 55, and 65 foot levels. Each contained some minnows, perch, and a young smallmouth black bass. The cages were examined at 1.45 p. m., and it was found that all of the fish in the two upper cages were living while those in the two lower cages were all dead. Late in the afternoon of the same day, with the aid of Doctor Welch, records of temperatures were made and water samples taken from the 49 and 55 foot levels. The temperature at 49 feet was 62½°; at 55 feet, 51.6°; and at 65 feet, 50°. The oxygen content at 49 feet was 5.28 c. c. per liter and at 55 feet 2.6 c. c. At 49 feet pH was 7.6, and at 55 feet 7.1. These data indicated that the lowest limit at which fish could live was somewhere in the thermocline.

Tests made August 6 at Station A, in connection with class work, indicated that fish could not live at as great a depth as at Station B, and also that the thermocline was not as far down. In the afternoon of the following day, with the aid of Doctor Welch, who made the chemical examination, the following data were secured:

August 7, 1920, Station A

	Depth			
	45 feet	47½ feet	50 feet	52½ to 70 feet
Temperature, °F	65.8 to 70.4	64	58	51.6 to 46.5
Oxygen, c.c. per liter	5.52 to 7.29	4.33	2.28	0.028 to 0
pH	7.8 to 8	7.7	7.3	7.0 to 6.9

At 4.25 p. m. fish were placed in baskets at 37½, 42½, 47½, and 53½-foot levels. At 8.30 p. m. the fish in the two upper baskets were in good condition; some of those at 47½ feet were all right and some were ailing; all at 53½ feet were dead. During the two following days (August 8 and 9) the tests were continued, with some shifting of depths of the cages, with the general result that it was shown that fish lived very well at 45 feet; at 47½ feet some would live for a day or more but not in good condition; and at 50 feet, or below, all soon died. A young sucker and a young bullhead were left at the 45-foot level until August 17, when they were still in good condition and were released.

During August, 1921, tests were made at Station A on five different dates and at Station B on three dates. Two of these latter tests were unsatisfactory because of the continued high wind and rough water which subjected the buoys to which the cages were attached to constant motion. This presumably accounted for the death of most of the fishes in the upper cages, which, under normal conditions, should have lived. In the tests made in 1921 the cages were placed at 2½-foot intervals. Where slight discrepancies occur between the depths of the cages and the levels at which temperature and chemical records were made, they are due to the fact that on checking up the distances on the rope to which the baskets were attached and by taking for a standard the rope used in taking water samples for analysis such discrepancies were found to exist. Different ropes of varying texture and previous treatment often differ in the amount of change in length which they undergo when subjected to tension under water.

The chemical data in the following records were all obtained by Dr. Minna Jewell. The first of the tests in the summer of 1921 was at Station A on August 5, when the following data were secured:

	Depth					
	37½ feet	40 feet	42½ feet	45 feet	47½ feet	50 feet
Temperature, °F	70.6	68	63	59.5	55.6	53.6
Oxygen, c. c. per liter	4.24	2.35	0.95	0.09	0	0
pH	7.8	7.5	7.3	7.2	7	7

Fish in cages placed at 38 and 40½ feet remained in good condition until the end of the test, several hours later. All of the fish of each of two different sets, including perch, minnows, and mud minnows, died within two hours when put in cages placed at 43 and 45½ feet. One week later the thermocline was somewhat deeper, as shown by the following data:

August 12, 1921, Station A

	Depth					
	40 feet	42½ feet	45 feet	47½ feet	50 feet	52½ feet
Temperature, °F	68.5	68	65.4	58.3	54.9	52.6
Oxygen, c. c. per liter	5.47	5	1.7	0.96	0	0
pH	8.4	8	7.3	7	7	6.9

At 3.08 p. m. about 15 perch (young of the year) were put in each of the cages and placed at 42, 44½, 47, and 49½ feet. At 4.23 p. m. all of those in the two lower cages were dead and all of those in the two upper cages were in good condition except one that had died in the uppermost cage. Those left in the two upper cages were in good condition when examined again at 7 p. m. At 7.45 a. m. of the following day 9 fish were in good condition at 42 feet and 8 at 44½ feet. At 1.45 p. m. only 4 were living at 42 feet and 1 at 44½ feet. A test made August 16 and 17 gave data similar to others and need not be described.

Another depression of the thermocline is shown by the following data:

August 19, 1921, Station A

	Depth			
	45 feet	47½ feet	50 feet	52½ feet
Temperature, °F	66.2	63	54.9	53.8
Oxygen, c. c. per liter	3.6	1.84	.59	.42
pH	8.1	7.4	7.0	6.9

The above records were made at 6.30 a. m., and at 8.15 a. m. fish were placed in three cages at the following depths: In a cage at 45 feet were four perch, a log perch, and a young smallmouth black bass. These had already been in the cage at that depth for two days and still seemed in good condition. A cage containing a young bullhead, a young smallmouth black bass, and three 2-year-old perch was placed at 47½ feet. A cage with similar contents was placed at 50 feet. At 11.20 a. m. the fish at 45 feet were in good condition. At 47½ feet the bass and one perch were dead but the others seemed to be in good condition. At 50 feet all the fish were dead. At 3.30 p. m. all of the fish at 47½ feet were dead and those at 45 feet were in good condition. At 6.40 p. m. those at 45 feet were still all right, and in the cage at 47½ feet were placed young perch, young *Lepomis gibbosus*, and young rock bass. At 7.30 a. m. of the following day all of the fish at 47½ feet were dead, and in the cage at 45 feet a young bass and two perch were still living, but the others were dead. The fish of that cage had been confined at that depth for three days. The lowest limit at which fish could live was very definitely between 45 and 47½ feet, and in the upper portion of the thermocline.

The last test of the season at Station A showed a still further depression of the thermocline and a corresponding change in the depth at which fish could live.

August 22, 1921, Station A

	Depth				
	45 feet	47½ feet	50 feet	55 feet	70 feet
Temperature, °F	64.4	64	61	51.4	48.8
Oxygen, c. c. per liter	4.84	3.70	2.35		0
pH	8.4	8.0	7.3		6.8

At 1.05 p. m. fish were placed at 45, 47½, and 50 feet, as follows: A cage placed at 45 feet contained 7 young perch, 1 yearling sucker, 2 yearling rock bass, and 2 young bullheads. A cage placed at 47½ feet contained 5 young perch, a half-grown sucker, a young *Lepomis gibbosus*, 2 minnows, and 3 young bullheads. A cage placed at 50 feet contained 2 young perch and 3 young bullheads. The perch used were mostly 2-year-olds and the remainder were yearlings. At 3.15 p. m. the fish at 45 feet were all in good condition, and those at 47½ feet were also, except the two minnows, which were ailing. In the cage at 50 feet the perch were dead and the bullheads nearly dead. At 7.05 p. m. the fish at 45 feet were in good condition and were transferred to Station B for a test to be described later. At 47½ feet the two minnows were dead and the *L. gibbosus* was ailing. These were discarded and the others, still in good condition, were transferred to Station B. The fish at 50 feet were all dead. The lowest limit at which fish could live at Station A was about 7 feet deeper than on August 5, two and one-half weeks previous.

As already stated, high winds and rough water made two of the three tests at Station B in 1921 quite unsatisfactory. The fish were necessarily confined in a relatively small "live box" in a rowboat for an hour or more, while journeying to the station and while temperature and chemical records were being made. During all of this time they were being jostled about because of the motion of the boat, due to the rough water. After they were submerged, the cages containing them were being continually jerked about because of the action of the waves on the float from which the cages were suspended. Although unsatisfactory, the records are not without significance.

In connection with the first test of the season at Station B we have the following data:

August 13, 1921, Station B

	Depth				
	47½ feet	50 feet	52½ feet	55 feet	60 feet
Temperature, °F		66.3		56.5	53.9
Oxygen, c. c. per liter	4.69	2.95	0.77	0.3	0.06
pH	8.2	7.5	7.2	7	7

At 3.15 p. m. four or five perch (1 or 2 years old) were put in each of the four cages, which were placed at the 47½, 50, 52½, and 55 foot levels. About one hour later the cages were raised and examined as well as the rough water would permit without undue rough treatment of the fish. Of those in each of the two upper cages about one-half seemed to be in good condition and the others were ailing. Those of the two lower cages were all dead or dying. The cages were next raised on the morning of the 15th, when the fish were all found to be dead and more or less bruised.

The last test at Station B and the last of the entire series was in some ways quite significant. Fish were placed at 7.30 p. m. on August 22, but the records were obtained on the following day.

August 23, 1921, Station B

	Depth					
	52½ feet	55 feet	57½ feet	60 feet	62½ feet	65 feet
Temperature, °F		65	64.5	64	60	54.6
Oxygen, c.c. per liter	4.87	4.87	4.87	4.65	1.93	0.35
pH	8.3	8.3	8.2	7.7	7.3	7.1

Five bullheads, 1 smallmouth black bass, and 8 young perch were put in a cage, which was placed at the 52½-foot level. The fish that had been in a cage at the 45-foot level at Station A were placed at 55 feet. The fish and cage that had been at 47½ feet at Station A were placed at 57½ feet. Several young bullheads of the season were also included in this cage. At 10 a. m., after the data in the table above had been secured, the cages were raised, and it was found that the fish that had been at 52½ feet were in good condition, with the exception of one perch that had died and was removed. Those that had been at 55 feet were in good condition, except a perch and a yearling sucker that had died and were removed. Those that had been at 57½ feet were in good condition, except a perch that had died and one that was ailing. These were removed and several fresh specimens were added to this cage, including a few perch, a smallmouth black bass, and two mud minnows. Each of the cages was now placed at a level 5 feet below that which it had previously occupied. The one that had been at 52½ feet was now placed at 57½ feet and the others at 60 and 62½ feet, respectively. At 2.10 p. m. the cages were again raised, and it was found that in the one that had been at 57½ feet all of the fish were in good condition except two perch. Of those that had been at 60 feet all were in good condition except one perch that had died and another perch and a rock bass that were ailing. Of those that had been at 62½ feet all were dead except a few bullheads which were nearly dead.

The fish in the 60-foot cage had been confined for over 24 hours, having been at the 45-foot level at Station A for 6 hours on the previous afternoon and then transferred to Station B, where they were at the 55-foot level for over 14 hours and then at the 60-foot level about 4 hours; and yet the majority were in good condition, although they had originally been obtained from shallow water. Some of the fish in the 62½-foot cage had had an experience similar to that just described, and others were fresh specimens put into the cage only about 4 hours before; but the difference of 2½ feet meant the difference between life and death. The data in the last table furnish the explanation. The fish in the 62½-foot cage were in the thermocline with reduced oxygen and unfavorable hydrogen-ion conditions.

A similar change in conditions 20 feet nearer to the surface was found at Station A on August 5, with a corresponding effect on the fish. Fish could live at 40½ feet but died at 43 feet, just as in the last test they could live at 60 feet but died at 62½ feet.

The results of these observations very definitely answered one question that was in mind when the tests were planned. The lowest limit of the body of water that supplies the conditions necessary for fish to remain alive and in good condition is in the upper portion of the thermocline. In this upper part of the thermocline there is a marked decline in the amount of available oxygen and a rapid adverse change in the hydrogen-ion conditions, indicated by the reduction in the numerical value of the pH index. The expression "upper portion of the thermocline" is somewhat indefinite, and further tests may show that a statement placing the lowest limit of the habitable region in the upper quarter or upper third of the thermocline layer is warranted. No attempt was made to determine which of the various factors involved may be most potent in fixing the lower limit of the habitable part of the lake.

SUMMARY

The results of a considerable number of tests made in Douglas Lake, Mich., show a very definite and close correlation between the lowest limit of the body of water in which fish could remain alive and the upper portion of the thermocline. During August, 1921, the position of the upper portion of the thermocline at one station shifted from a depth of about 40 feet to one of 47 feet, and there was a corresponding variation in the depth at which fish could live. At another station, where the depth of the upper portion of the thermocline shifted from about 50 to 60 feet, there was a corresponding change in the depth at which fish could remain alive. They remained in good condition in cages placed at the depths mentioned, while those in cages placed at a level 2½ feet lower down soon died. In each instance the fish in the lower cage were in water having decidedly less oxygen and less favorable acidity conditions, and these factors, rather than that of mere depth alone, determined the lowest limit at which the fish could live. No attempt was made to discover which of the unfavorable factors was most potent.

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BLACK TUMOR OF THE CATFISH[1]

By RAYMOND C. OSBURN
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A conspicuous and very unsightly disease of the common bullhead, or hornpout (*Ameiurus nebulosus* LeSueur), appeared a few years ago in a pond at Waquoit, near Falmouth, Mass. The tumorous excrescences produced by the disease are so striking that it seems almost impossible that no mention of it has been made in the scientific literature. Ichthyologists and fish-culturists consulted have professed their ignorance of the existence of the disease, and examination of the literature of fish pathology proved futile.

The keen-eyed Thoreau, however, did observe the bullheads of the Concord River to be affected with this trouble more than 70 years ago. I should have overlooked this reference to it but for the kindness of Henry W. Henshaw of the United States Biological Survey, who called my attention to certain statements in Thoreau's "Journal." Under date of July 10, 1852, that writer states: "One of these large pouts had a large velvet-black spot, which included the right pectoral fin; a kind of disease which I have often observed on them." The location was on the Concord River. Later (July, 1858) Thoreau again wrote in his "Journal": "I see a pout this afternoon in the Assobet" (a tributary of the Concord) "lying on the bottom near the shore, evidently diseased. * * *. Nearly half the head, from the snout backward diagonally, is covered with an inky-black kind of leprosy, like a crustaceous lichen." There can be no doubt that Thoreau observed the disease which forms the subject of the present paper, but it seems strange that so long a period should elapse before such a striking malady should again come to the attention of a naturalist.

In the summer of 1917, while I was spending a short time at the Marine Biological Laboratory at Woods Hole, Mass., the late Vinal Edwards, collector for the Bureau of Fisheries, brought me a specimen of the diseased fish and asked my opinion of the nature of the growth. I took the opportunity to visit the pond where the disease occurred and collected some more material for preservation for sectioning and made some photographs. The best I could do at the time was to pronounce the disease some form of a tumor, and this opinion was concurred in, without any further information, by several pathologists to whom material was submitted.

In the summer of 1919 the Bureau of Fisheries made possible my further study of this disease, and I spent six weeks at the Woods Hole station. My results, though not complete in every detail, have been satisfactory.

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[1] A very brief account of this disease has already been published in Bureau of Fisheries Doc. 896, Progress in Biological Inquiries, 1920, p. 17.

So far as known, the disease at present occurs in only one pond, a small natural lake of some 10 acres, situated on the property of Dr. L. C. Jones, of Falmouth, Mass. Doctor Jones first observed the tumors and submitted specimens to Mr. Edwards. I owe him many thanks for assistance in obtaining material and for various observations.

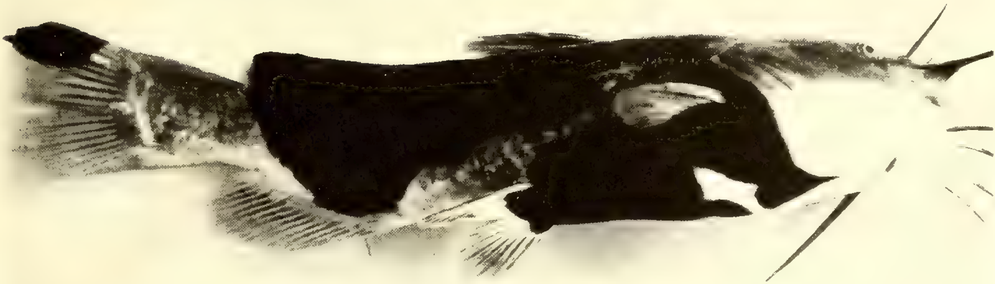
GROSS DESCRIPTION OF THE TUMOR

In the younger stages the tumors appear as intensely black areas of variable size and form in the skin of the fish (figs. 1, 2, 3, and 4). With later development these areas become thick and warty looking, with a very irregular surface, which sometimes, especially on the lips, may be fimbriated (fig. 4). Though at first the skin is only slightly thickened (figs. 1 and 7), the tumors may eventually rise 6 or 8 millimeters, or even more, above the level of the surrounding skin (fig. 3). They are soft to the touch and, in older tumors, the slightest pressure causes the extrusion of any inky black fluid. This color, as will be seen later, is due to the presence of enormous numbers of a minute black coccoid bacterium.

Any part of the skin may be affected, but the tumors are more commonly found on the fins and lips, parts which are especially subject to abrasion and are thus exposed to direct infection. In the majority of cases the skin on the outside of the body only is affected, but not infrequently tumors on the lips spread to the inside of the mouth (fig. 4, tumor on upper jaw). Vinal Edwards told me that he had seen one specimen in which the tumor had extended across the roof of the mouth and down the esophagus into the stomach. I observed one case in which the tumor, originating on the side of the body near the pectoral fin, had spread forward through the branchial chamber, involving part of the gills, and extended across the floor of the mouth to the lower jaw. In one case a tumor originated on the roof of the mouth.

Development proceeds so slowly that the rate of growth has not been determined. The tumors have been observed in all stages of development, from small spots less than 3 millimeters in diameter to areas involving more than one-third of the skin of the fish, and from cases in which the skin was scarcely thickened to those in which the tumor projected 8 or 10 millimeters above the natural surface. As a rule the larger tumors are more mature and much thickened; but this does not necessarily follow, for I have seen cases in which a tumor covering several square inches was scarcely raised above the surface (fig. 1) and others in which the tumor was as high as its diameter.

In spite of the tendency to spread laterally, there is no evidence of metastasis, and the deeper tissues beneath the tumor do not seem to be invaded; at least, in none of the material sectioned is there any evidence of such an invasion below the lower layer of the dermis, except that in older tumors the connective tissues between the muscles may be involved to some extent. Even in these cases the disease does not appear to penetrate to any considerable depth. On the fins the tumor frequently affects the entire substance, and a tumor originating on one side will penetrate to the opposite side. Perhaps this is to be expected, since the fins consist almost entirely of connective tissues.



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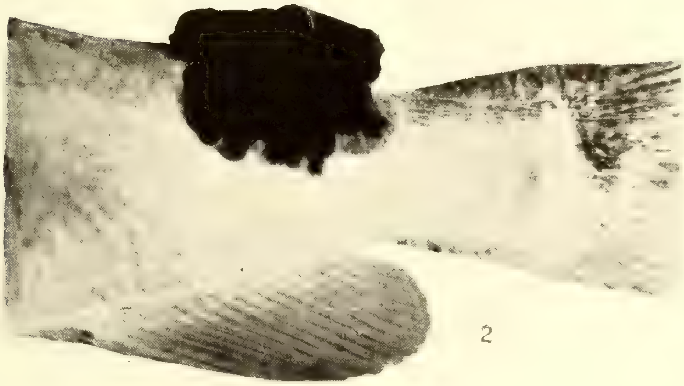

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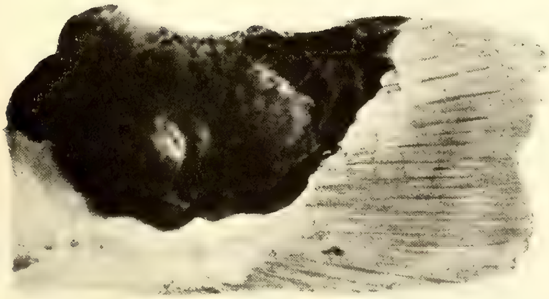

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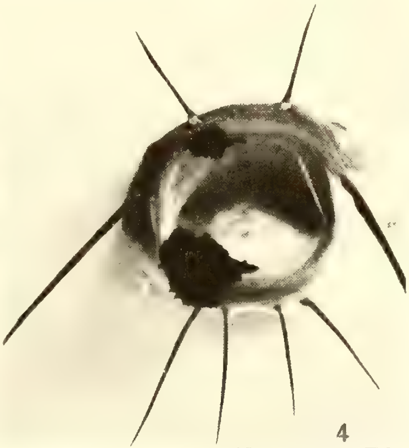

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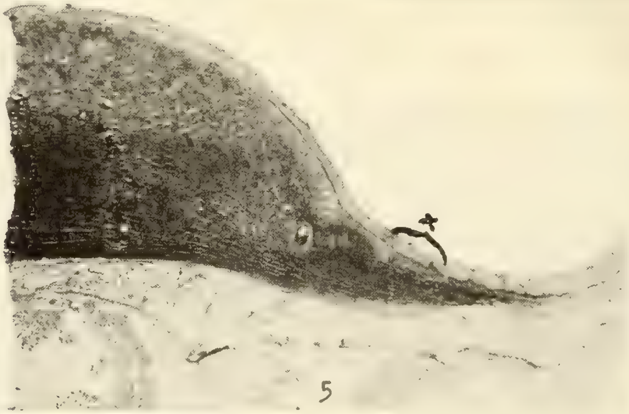
FIG. 1.—Extensive infection of a 9-inch fish. The tumors are still in the "young" stage, scarcely raised above the surface. The areas of dense black seem to indicate four centers of infection.

FIG. 2.—"Old" tumor involving all of the adipose fin and extending downward on both sides. A slight margin of younger growth is seen about the base of the older, dense black portion.

FIG. 3.—An "old" tumor involving the caudal peduncle and the base of the caudal fin, extending on both sides. The highest portion of this tumor is nearly half an inch above the natural dorsal line.

FIG. 4.—Tumors on the lips. That on the lower jaw is "older" and somewhat fimbriated on the surface. That on the upper jaw involves a portion of the oral surface. The left maxillary barbel shows infection in a very young stage.



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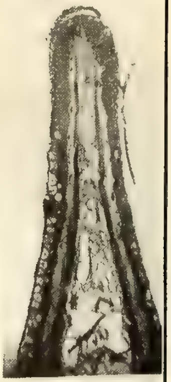

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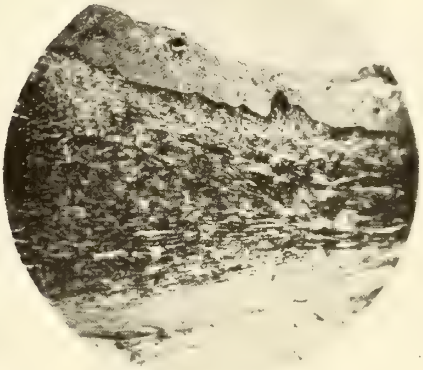

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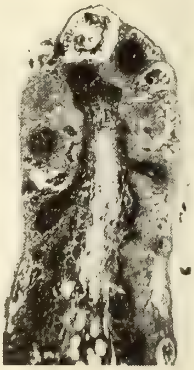

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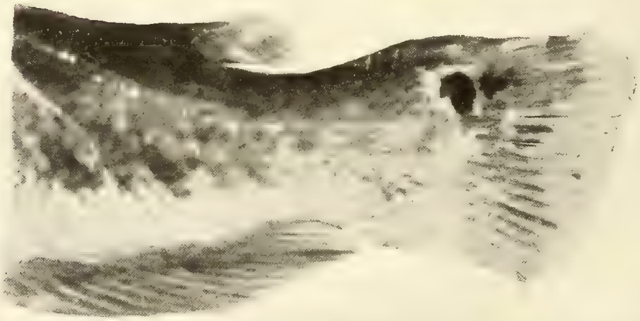

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Fig. 5.—Microphotograph of a section through an older but as yet unbroken tumor. The epidermis is still continuous over the surface. The black area indicates the thickening of the dermis—5 millimeters in thickness at the thickest portion shown. The portion marked *X* is shown enlarged in Figure 6.

Fig. 6.—Microphotograph under higher power of the portion marked *X* in Figure 5. The extent of the dermis is evident, and comparison with the right end of Figure 5 will indicate the amount of thickening above the normal. The extrusion of a lobe of the tumor into the epidermis is shown a little at the right of the center. The rounded black object in the epidermis at the left of the center is a section of another such lobe, and a third portion shows near the left border.

Fig. 7.—Microphotograph of section of adipose fin, fully infected, but in an only slightly advanced condition.

Fig. 8.—A similar section of an adipose fin at a more advanced stage of the disease. The connective tissue of the fin is entirely involved. The rounded cavities are large cystlike spaces filled with the bacteria, most of which were lost out in making the slide.

Fig. 9.—A "young" tumor at the base of the caudal fin, experimentally produced by inoculation, as indicated in the text. Two months after inoculation.

MICROSCOPIC STUDY

Under the lower powers of the microscope the sectioned material of the tumor appears as a mass of small black bodies, usually more or less rounded, so thickly distributed among the connective tissue fibers of the skin that they almost completely obscure everything else. These bodies appear to be cystlike masses of the cocci, and scattered individual cocci may also be observed everywhere in great numbers.

In smears made from fresh material the same cystlike bodies are present, along with scattered cocci, and under the oil immersion the cocci within the cyst may often be seen in active Brownian movement. It was at first supposed that this movement might be due to some activity on the part of the organism, but in smears made from material macerated in strong potassium hydroxide the same movement was evident. In fresh smears the cysts may be seen to break under slight pressure of the cover glass, liberating large numbers of the cocci. The cocci are densely black with an endogenous pigment, and they are so abundant that it is difficult to examine sectioned material with satisfaction, even when cut to only two or three microns.

From my observations it appears that the tumor begins its development in the outer layer of the dermis and later involves all of this layer, expanding it to many times its original thickness. The dermal blood vessels are enlarged, but I have seen no evidence of bleeding, even in old tumors. As the disease progresses small fingerlike projections of the tumor invade the epidermal layer and make their way to the surface (figs. 6 and 8). Eventually the epidermis sloughs off over the older portion of the tumor, leaving a ragged surface formed by the dermal connective tissue fibers and the substance of the tumor. A slight pressure of the tumor at this stage causes the extrusion of the inky-black fluid containing the cocci, as indicated above.

STUDIES AND EXPERIMENTS

As some form of fungus had been suggested as the cause of the disease, my first studies were directed toward this point. Ordinary fish fungus (*Saprolegnia* sp.) is not black, but some species of *Aspergillum* and some other fungi do produce black pigment. Some fishes were found with fungus on the tumors, but a little study revealed the fact that this fungus was not black and that it sometimes occurred elsewhere on the same fish where the skin had been abraded and where there was no evidence of the black tumor. Moreover, when growing in the tumor, the fungus was not found in the deeper portion. Careful search was made for any fungus in sectioned and fresh material and by macerating with strong potassium hydroxide, which breaks down the animal tissue but leaves fungi intact. Fungus as a cause of the tumors was thus thrown out of consideration.

The question of an animal organism as the causative factor was also considered, especially as the Myxosporidia often produce tumorlike growths, but no evidence of any such could be observed.

The hypertrophy of the pigment layer of the skin, due to stimulation by an organism or otherwise, at first seemed a possibility. The extension of the black tumors into unpigmented areas of the mouth, gill chamber, pharynx, and even down into the stomach (according to Edwards), and the origin of the tumor in the mouth, as observed in one case, did not favor this view. The presence of the black granules throughout the tumor and the growth of black colonies in culture rendered the idea untenable.

That the minute black granules observed under the higher powers of the microscope could be bacteria did not at first seem likely. Bacteria which secrete any form of pigment intracellularly are rare, and the granules are so minute (averaging only one-third of a micron) that little could be made of them, even under the oil immersion, though diploid individuals were common enough. The conviction was finally forced upon me that we have to deal with a bacterial tumor of slow growth and of a rather benignant type, which, however, bids fair to destroy the catfish in this pond and which, if permitted to spread, may become a menace over a larger area.

Cultures and inoculations were made to determine whether the organism could be grown or transmitted. In this work I was fortunate to have the assistance and advice of Dr. W. W. Browne, of the College of the City of New York, and Miss Helen Mitchell, of Yale University, bacteriologists on the station staff for the summer of 1919.

It was found very difficult to grow the organism in cultures, but a measure of success was achieved by combining extract of catfish tissues with agar, according to a commonly approved procedure of bacteriological study. The growth was so slow that at the end of two weeks the largest colonies were only 4 or 5 millimeters in diameter. Contamination of the cultures was thus almost unavoidable, though a few of the many cultures made were successful to the extent above indicated. Incubation at higher temperature did not seem to hasten the growth, and cultures at air temperature grew about as well. The colonies in culture have the same intense black color as the tumors, and, on microscopic examination, the cocci showed the same size and appearance.

Inoculations of uninfected catfish of the same species from another pond were made by the following methods: (1) By hypodermic injection of the black fluid from a tumor; (2) by scraping the skin and rubbing in portions of a fresh tumor; and (3) by grafting portions of tumor under the skin. The catfish so inoculated were left at Woods Hole until the end of October, two months after inoculation, when they were preserved in formalin and forwarded to me. Some of these showed undoubted tumors of small size, indicating that the disease is directly transmissible (fig. 9). Unfortunately some of the fishes were allowed to become mixed up after I left the laboratory, so that it is impossible for me to state whether one method was more successful than another, though there are specimens of all three types that produced tumors.

The organism causing the tumor appears to be a very minute Coccus, and seems to have been hitherto undescribed. It is perfectly round; it averages about one-third of a micron in diameter, ranging from one-fourth to one-half a micron; and it secretes endogenously a black pigment. Unstained smears show the organism, because of the pigment, as well as stained preparations. In smears the individual cocci are not black when viewed under the oil immersion lens, but are distinctly dark. In mass they appear absolutely black. Diploid forms, indicating cell division, may be observed commonly both in living and preserved material. Not being a bacteriologist, the writer will not attempt to describe or name the species.

As to the fatality of the disease, there is no definite information. Doctor Jones informs me that he has seen no dead fish, but the nature of the pond is such that they would not readily be observed, for the shores are brushy to the water's edge and there are no beaches. Moreover, there is much vegetation in the pond, especially near the shores, which would help to make the discovery of floating dead specimens difficult. Certainly the disease is not rapidly fatal, for fish with well-developed tumors have been kept under observation in aquaria in the laboratory for six weeks without showing any changes except for some slight growth in the area and thickness of the tumors. It would thus appear that there is no active systemic poison or toxin liberated, at least at the time of the year during which these studies were made. Fish with large tumors were taken with hook and line, even those with large tumors on the jaws accepting the bait readily. However, it was noted that old tumors, from which the epidermis had been lost, were frequently infected secondarily with *Saprolegnia*, and there seems little doubt that this fungus, which only enters abraded surfaces, would soon cause the death of the fish.

Doctor Jones believes that the disease has spread very rapidly since the summer of 1916, when its presence was first observed. In 1917 about half of the fish taken had tumors of various sizes and degrees of development. In the summer of 1919 it was a difficult matter to find any uninfected catfish in this pond. No doubt the habits of the bullhead in schooling together make the transmission of the disease an easy matter. It was not noted on other species of fish in this pond during my work there nor on the same species of catfish in neighboring ponds. That this disease is capable of attacking the bullheads in other ponds is evident from my inoculation experiments. Under date of February 2, 1921, Doctor Jones wrote me as follows:

> A man who has been fishing through the ice on this pond tells me that he caught a pickerel the other day which was covered with the same dark colored spots observed on the hornpout. Unfortunately he had disposed of the specimen, but so far as I know this is the only instance where the disease has been observed on any fish except the hornpouts.

As the evidence in this case is not complete, it may be well to suspend judgment as to whether the disease is capable of attacking other species than the bullhead.

In the course of my work no measures satisfactory for the control of the disease have been suggested. Salt and potassium permanganate solutions, both of which are useful in the control of *Saprolegnia*, were tried on individual specimens, but without any noticeable beneficial effect. Of course, it should hardly require mentioning that no species of fish from this pond, whether showing such infection or not, should be planted elsewhere.

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GROWTH AND DEGREE OF MATURITY OF CHINOOK SALMON IN THE OCEAN

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INTRODUCTION

The rapid increase in the amount of trolling and purse seining for salmon which has taken place along the Pacific coast during the past few years has directed attention toward this phase of the salmon industry. The general consensus of opinion of those interested in conservation is to the effect that these methods of taking salmon are, under certain circumstances at least, destructive and undesirable. The fishing on Swiftsure Bank, off the coast of Washington, was reported on a number of years ago by Dr. C. H. Gilbert (1915), who found that the silver salmon (cohoes) taken by purse seines on the bank, "especially in the first part of the season, are far from having attained their full growth, although maturity is but a few months distant." Of the spring salmon (the chinook) he makes the following statement:

> The spring salmon is taken in large numbers and furnishes a somewhat inferior product, with soft flesh, little oil, and poor color. Several thousand young of this species are captured during the season, 2-year-olds about a foot long with white, soft flesh—a total waste. The numbers of these are relatively small, as the great majority of the salmon on the bank are in their last season, but the loss is nevertheless serious and deplorable.

In 1920 Smith and Kincaid reported on the immature salmon taken off the mouth of the Columbia River, Grays Harbor, and Neah Bay during 1918. Later in the same year (1920) a more complete report by Smith gave the results of his investigations during 1918 and 1919. In both of these reports Smith gives the results of chemical analyses, which show that the product resulting from the canning of the immature fish is decidedly inferior to the standard grades in fat and protein content. He also presents figures that show something of the extent of the operations of both the purse seine and the trolling fleets, and concludes that "the taking of immature salmon in the Puget Sound and on the banks along the coasts of Oregon, Washington, and Vancouver Island is responsible for a great loss in one of the important food products of the region."

The "outside fishing," as it is commonly termed, has been increased by the addition of both purse seines and trolling boats, but the exact amount of this increase in the different regions where such fishing is carried on is difficult to determine. The purse seiners frequently move from one location to another, fishing wherever the greatest returns can be obtained. The trollers not infrequently (at least in Oregon and Washington) fail to take out licenses. Much of the trolling is carried on outside the 3-mile limit, and some of the trollers argue that it is not necessary for them to take out licenses to fish except in territorial waters. Furthermore, one fisherman often takes out licenses for more than one kind of gear—as for trolling and gill netting, or trolling and trapping—and trolls only a small part of the season. These factors make it practically impossible to determine with any accuracy the amount of increase in this outside fishing, but there can be no doubt that it has developed within the past few years into a very important factor and represents an increased drain on the resources of the fishery which may easily result in serious depletion. The number of trollers operating off the mouth of the Columbia River during the three seasons, 1919 to 1921, inclusive, was estimated at between two and three thousand, and the Columbia River District Troller's Union alone contained some 1,500 members. At the same time there were probably not less than 40 purse seines operating in the same region. This is in strong contrast to the condition in 1914, when there were only a few dozen trollers and possibly three or four purse seines operating off the mouth of the river.

One of the chief objections that has been raised to this "outside fishing" has been that it was destructive of immature salmon. The most casual observation shows that a considerable percentage of the fish taken outside are relatively immature. They average decidedly smaller than the fish taken inside, are feeding heavily, and observation of the gonads discloses the fact that these organs are relatively undeveloped in many of the individuals. The taking of fish one or more years before they will become mature reduces the population that will form the basis of the fishery one or more years later, at which time fishing operations of dangerous intensity will be brought to bear upon the reduced numbers. Such an increase in the intensity of fishing that will affect the abundance of salmon previous to maturity, when they are comparatively small and of poor quality, and acting on a resource already showing evidence of depletion, is unquestionably a dangerous development.

In a preliminary report dealing with the subject of this paper (Rich, 1921a) the writer made the following statement:

> The determination of the age by means of scale studies will not alone give a sufficient index to the degree of immaturity since there is such a wide range in the age at which these fish reach the spawning stage—from 2 to 6 years. If the percentage of individuals of different ages among the mature fish were constant, it would be possible, from a determination of the percentage of fish of different ages taken by troll and purse seine in the ocean, to estimate the percentage of fish of different degrees of maturity. This, however, is not the case. The percentage of fish of the various age groups varies greatly at different times among the mature fish and also among those taken in the ocean. Presumably these variations, at least among the mature fish, are due quite largely to racial differences, but our present knowledge of the various races of chinook salmon is far too limited to aid in segregating the races from mixed lots. Even if our knowledge of the races were complete it might well be that they could not be identified and segregated accurately and fully enough to serve this purpose. It is apparent that some other means than the determination of the age is necessary in order to learn the percentages of mature and immature fish taken in the ocean and their relative maturity.

It has been found, as will be subsequently shown in detail, that the size of the eggs gives a fairly accurate means for determining how soon the females will mature. During a field trip to Monterey, in 1915, it was noted that there was considerable variation in the size of the ova, and a series of egg samples was collected. It was thought that from a study of the eggs something might be learned of the percentage of mature and immature fish taken by troll in Monterey Bay. These eggs were collected from the cleaning tables and no attempt was made to collect data and scales from the fish from which the eggs were taken. Nothing was done with this collection until the summer of 1918, when the matter was again brought up for consideration. On examining the samples, the fact became apparent that several reasonably distinct sizes of eggs were to be found, which presumably represented different degrees of maturity. (See Table 23, p. 86.) In order to secure more complete data, another collection was made at Monterey in the summer of 1918, and in this case measurements and scales were secured along with the egg samples. The study of this collection confirmed the earlier observations as to the presence of fairly distinct size groups of eggs, and the examination of the scales showed a high degree of correlation between age and the size of the eggs. (Table 25, p. 87.) Extensive collections have since been made from the fish taken by troll off the mouth of the Columbia River, and it has been found that, while the determination of maturity is not as simple a matter as it had first appeared, the general features will hold good.

It is obvious that this method is applicable only to the females and no method has yet been devised for accurately determining the relative maturity of the males. It was thought at first that the percentage of males of various degrees of maturity could be calculated with reasonable accuracy from the percentages of males and females found among the mature fish in the stream if once the percentage of mature and immature females taken outside was known. If it were not for disturbing factors this could easily be determined, *for each separate age group*, by means of the following proportion: Percentage of males taken inside : percentage of females taken inside :: percentage of males taken outside which are mature : percentage of females taken outside which are mature. It has been found, however, that the proportions of males and females found among the mature fish taken inside the river at different times during the season is so variable as to make a calculation of this nature very unsatisfactory on the basis of the data at present available. No attempt has been made, therefore, to do this. The males undoubtedly show a decided tendency to mature younger than the females, and for this reason the total percentage of immature fish taken outside is somewhat less than the percentage of immature females. Just how much allowance should be made for this factor it is impossible to say, but in any event it would not alter materially the general conclusions arrived at from a study of the females alone. It may be mentioned that, from the standpoint of conservation, a knowledge of the effect of a fishery upon the supply of females is of much more importance than a similar knowledge of the effect upon the supply of males.

In the preliminary report mentioned above an outline of the method used in determining the relative maturity was given, together with a brief summary of the more important results that had been obtained at that time. The following report embodies the results of more recent studies and gives in detail the data on which the conclusions are based.

The writer wishes to acknowledge his indebtedness to Dr. C. H. Gilbert, of Stanford University, whose advice has been constantly available throughout the preparation of this report. Many helpful suggestions have been obtained from Dr. F. W. Weymouth, of the physiology department at Stanford University. Some of the earlier work was done at the Hopkins Marine Station at Pacific Grove, Calif., but most of it was done in the laboratories of the zoology department of Stanford University.

METHODS

DETERMINATION OF AGE

Although a detailed study of the life history and scale growth of the chinook salmon still remains to be made, the main features are sufficiently known to permit of a reasonably accurate determination of age by the usual examination of the scales.

The determination of the age of fish by means of a microscopic examination of their scales has been used so extensively during the past two decades that a detailed description of the method seems unnecessary. It depends upon the fact that the rate of growth of the fish varies materially at different times of the year. During the spring and summer, in general, growth is more rapid, and during the fall and winter it is slower. The scales of many fish, including the salmon and trout, bear series of concentrically arranged ridges on their outer surface. On account of their concentric arrangement these are known as rings or circuli. The scales increase in size with the growth of the fish, and circuli are added at the margins. The scales are never normally shed, but increase in diameter by these accretions to their margins, and in thickness by additions to the inner surfaces. The markings formed by the circuli are therefore persistent throughout the life of the fish. The arrangement of these circuli is characteristically modified by variations in the rate of growth of the fish. During the more rapid growth of the spring and summer the rings are spaced relatively widely, but during the period of slow or of perhaps no growth, which obtains during the fall and winter, the rings are crowded together closely and are frequently more or less broken and imperfect. The complete year's growth, therefore, consists in a "summer" band of relatively wide rings followed by a "winter" band of narrow rings. By counting the number of "summer" or "winter" bands the age can readily be determined.

Weymouth (1923) has given a brief though admirable discussion of the various methods of determining age. In answering certain criticisms that have been made of the method of age determination of fishes by means of scales, he makes the following pertinent observations:

> These objections are not valid, however, in the case of a number of species of fish, where the annual nature of the marks rests on no assumption of any kind, but on direct observation. In some a study of the scales throughout the year has clearly shown that the ring is formed during the winter and only once each year. In others it has been shown that the number of rings agrees with the known age of fish kept in captivity or of marked fish recaptured after known periods. The soundness of these conclusions is not affected by the fact that in certain species the rings are less distinct and hence in these cases may be an unreliable guide to age, nor that incompetent or hasty workers may have reached incorrect conclusions in any species.

Although this method of determining the age of fishes appears to be simple and of easy application, in practice serious difficulties are frequently encountered. The relative approximation of the rings is merely a reflection of the rate of growth prevailing at the time the rings were formed. Not infrequently factors cause variations in the rate of growth which are unassociated with the seasonal variations responsible for the formation of "summer" and "winter" bands. As a rule, the cause of these incidental variations is unknown, although the present writer has suggested causes for some of the minor variations observed in the scale growth of chinook salmon previous to or during their seaward migration (Rich, 1920). Snyder (1922 and 1923) has also discussed the causes responsible for unusual checks on the scales of chinook salmon in the Klamath River. In the case of the chinook salmon the determination of age is further complicated by the fact that the young fish, at least in the Columbia River, may migrate seaward at any time after they emerge from the gravel of the spawning beds up to an age of 18 months or more. There are, therefore, many difficult and puzzling characters in the scale growth which must be worked out before a completely satisfactory analysis can be made, but a full consideration of the problems connected with age determination in the chinook salmon lies outside the scope of the present paper. The age determinations will, therefore, be presented without further discussion of the details. It may be remarked that the author, in the course of an intensive study of the scales of several thousands of chinook salmon from the Columbia River, has found nothing that conflicts with the main conclusions reached by Gilbert in his initial paper dealing with scale studies (Gilbert, 1913). In all cases where the interpretation of the scales was in doubt the individuals have been omitted from the tables. This procedure may have eliminated some few small categories, but these would not materially affect the main conclusions that have been reached.

The lack of data bearing on the types of scale growth presented by the fish of the various coastal streams and of the various tributaries of the Columbia has made the study of the scales of the fish taken in the ocean an extremely difficult matter. Numerous more or less distinct types of scale growth could be described, but the description alone would have little bearing on the subject matter of this report, in view of the fact that it is at present impossible to assign the various types to particular streams or tributaries. It has been necessary, therefore, to omit a detailed segregation of individuals on the basis of racial differences and to segregate only into the main age groups. With the exception of age, the only other feature of the life history which has been used as a basis of segregation has been the general type of the early growth. Gilbert has shown in the report above cited (1913) that the chinooks of the Columbia River exhibit two distinct types of "nuclear growth" (the growth of the first year), forming what he terms the "ocean type" and the "stream type" of nuclei. The ocean type of nucleus is large, with rings that are relatively widely separated (figs. 27 to 33), and indicates that the fish migrated to the ocean early in its first year. The stream type of nucleus, on the other hand, is small, of closely crowded and more delicate rings (figs. 34 to 40), and characterizes the scales of those fish that have spent the entire first year in fresh water. An age group, in the sense in which the term is employed in this paper, comprises all of the individuals in a collection that are of the same age and that have the same general type of nuclear growth. Thus there are fish with ocean nuclei from 2 to 6 years old, and also fish with stream nuclei from 2 to 6 years old—a total of 10 age groups in all. Illustrations of typical scales of each group will be found in Figures 27 to 42.

DETERMINATION OF RELATIVE MATURITY

Mention has already been made of the fact that the determination of the relative maturity has been based upon variation in the size of the eggs.

The egg samples, as collected in the field, consisted in a small portion of the ovary. When the eggs were relatively small and the ovary but half an inch or so in diameter, a section of the ovary about 1 inch long was taken for a sample. When the eggs were larger, as in the nearly mature fish, a section of the ovary approximating 1 cubic inch in volume was taken. These egg samples were tagged with serially numbered tin tags and the number of the egg sample added to the other data recorded in the book in which the scales were preserved. The samples were preserved in 10 per cent formalin.

The size of the eggs has been determined by measuring 10 of each sample and taking the average. The larger eggs—those over 1 mm. in diameter—were measured in a simple device, which consists essentially of a small trough, V-shaped in cross section and with closed ends, which is graduated in millimeters. In use this is partially filled with water, the eggs are placed in a row in the bottom of the trough, and then are carefully pushed up to the zero end of the scale by means of a small piece that fits the bottom of the trough and on which is graduated a vernier, enabling one to read accurately to tenths of a millimeter. The reading is made when the first egg is in contact with the zero end of the trough and the eggs are all just in contact with one another. If too great pressure is applied, one or more of the eggs will be pushed above the others, so that the error in procedure is readily detected. When this happens it is necessary to push back the vernier, readjust the eggs, and repeat the operation. The measurement of 10 eggs by this scale gives, by simply moving the decimal point one place to the left, the average size of the eggs to hundredths of a millimeter, a degree of accuracy which is unnecessary in the great majority of cases. In preparing eggs for this measurement it is necessary to free them very carefully from the ovarian membranes, so as not to break the delicate egg membrane and yet to clear them of all shreds of tissue which might tend to affect the measurement. The smaller eggs—those less than 1 mm. in diameter—were measured by means of a microscope fitted with an eyepiece micrometer, carefully calibrated against a stage micrometer. In using this method it was necessary, of course, to measure the 10 eggs separately, and then the average of these measurements was found.

If one examines the eggs of chinook salmon taken in fresh water during their spawning migration, it is found that the eggs of different individuals vary only slightly in size. A similar examination of the eggs of females taken in the ocean discloses that there are wide variations in size. A group with eggs approximately the same size as those of the fish taken at the same time of year in the river can readily be selected. In addition to this group, however, many of the females have eggs distinctly smaller than any found among the spawning run in the river, and it is possible many times to separate these smaller eggs into two or more groups, even without careful measurement. When this observation was first made it seemed probable that each size group of eggs indicated a different degree of maturity, so that an analysis of the relative maturity of the fish in a given catch could be accomplished merely from an examination of a series of the ovaries. The assumption was that the fish with the largest eggs would mature and spawn during the year in which they were captured, that those with eggs falling within the next smaller group would mature during the next year, and so on. It has been found, on closer analysis, that while the size of the eggs alone forms a very satisfactory diagnostic character for distinguishing between fish that will mature during the year in which they are captured and those that will not mature for at least one more year, it can not be depended upon to distinguish between those that will mature in one year from those that will mature in two or more years. It has been found that the eggs grow in proportion to the rest of the fish until, approximately, the beginning of the growing season, which is destined to end in the maturing and spawning of the individual. With the onset of this last growing period, however, the rate of growth of the eggs is relatively accelerated and a differential growth sets in, so that the eggs gradually increase in size relative to the size of the fish. As a result, the eggs of the maturing fish are relatively larger than those of the immature specimens. This fact makes it possible to distinguish between those individuals that are maturing and those that will not mature for at least one year.

The observed differences in the size of the eggs of the immature fish taken in the ocean are due only to corresponding differences in the size of the fish. As will be shown later, there is a high degree of correlation between the size of the eggs and the size of the fish. The observation that the eggs may be grouped on the basis of size is dependent upon the fact that the differences in size between the younger age groups of chinook salmon, as in many other animals, is often so marked that the fish themselves fall into fairly distinct size groups corresponding to different ages, and the size groups of eggs is merely a reflection of this condition.

The acceleration of the growth of the eggs during the last growing season is shown clearly in Figure 1. This graph shows the proportional changes in the size of the eggs of fish with ocean nuclei during their third year—first, for those mature fish taken inside the river; second, for the mature fish taken outside; and third, for the immature fish taken outside. The points on this graph indicate the position of the weighted arithmetic means of the logarithms of the egg sizes.[1]

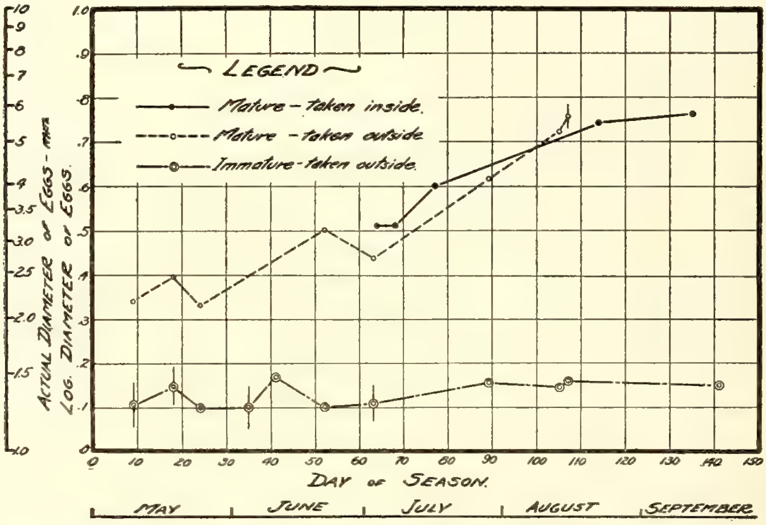

FIG. 1.—Changes in the sizes of the eggs of females in their third year, ocean nuclei, during the course of the fishing season. Columbia River and the ocean off the mouth of the Columbia

In addition to the fact that the eggs of the immature fish are distinctly smaller, it is apparent from Figure 1 that the slope of the curve for the mature fish is much steeper than that for the immature fish, indicating unmistakably that the eggs of the maturing fish are increasing in size, not only actually, but relatively, at the more rapid rate. If the two curves were projected back into the months preceding the opening of the fishing season, they would evidently meet some time in March or early in April, which would indicate that the differential growth probably begins at about that time.

This differential growth of the eggs of the maturing fish is shown in another way in the following table, which gives the proportional size of the eggs in relation to the length of the fish in a few selected groups chosen largely because they were better represented than the others.

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[1] See pages 24 and 25 for an explanation of the use of logarithms in this connection.

Table 1.—*Relation between diameter of eggs and size of fish (Columbia River chinook salmon)*

Age group	Date taken	Number of specimens	Average length in centimeters (L)	Average logarithm of egg diameter	Geometric mean of diameters of eggs (D) in millimeters [1]	$\frac{D\times 100}{L}$
In third year, stream nuclei, immature	May 8 to 10	18	48.11	$\bar{1}.9588$	0.909	1.890
	June 4	11	50.40	$\bar{1}.9480$	.889	1.763
	July 2	7	55.00	.0214	1.050	1.909
	July 28	7	59.00	.0756	1.190	2.017
	August and September	4	66.00	.1150	1.303	1.975
In third year, ocean nuclei, immature	May 8 to 10	100	61.00	.1043	1.272	2.085
	June 4	32	61.61	.0981	1.254	2.035
	July 2	26	66.50	.1085	1.284	1.930
	Aug. 13	6	70.33	.1430	1.390	1.977
	Sept. 18 to 19	7	70.72	.1500	1.412	1.998
In fourth year, ocean nuclei, mature	May 10	18	79.56	.3174	2.075	2.610
	June 21	10	86.40	.5100	3.230	3.740
	July 2	22	84.19	.5336	3.415	4.055
	July 28	40	89.33	.6406	4.370	4.890
	Aug. 13	63	93.50	.7243	5.300	5.670
In fifth year, ocean nuclei, mature	May 18	13	96.15	.4054	2.542	2.645
	July 2	11	95.40	.5792	3.796	3.978
	July 28	18	96.22	.6733	4.712	4.900
	Aug. 13 to 17	19	100.16	.7553	5.695	5.680

[1] The geometric mean of a series of measures is the number corresponding to the arithmetic mean of the logarithms of the original measures. Since the data on egg sizes has been handled in the logarithmic form (see pp. 24 and 25), it is convenient to use here the geometric rather than the arithmetic mean.

The ratio, $\frac{D\times 100}{L}$, given in the last column of this table, is 10 times the percentage of the length of the fish represented by the diameter of the eggs. The actual percentages are so small that it is more convenient to handle the values in this way.

The table shows that among the immature fish there is little variation in the relative size of the eggs as compared with the size of the fish. The ratio is practically the same in immature fish of the different age groups, and within a single age group there are no significant changes in the ratio during the season. This signifies that the size of the eggs and their growth is closely proportional to the size and growth of the fish. In the case of the mature groups, however, a constant and marked increase in the ratio $\frac{D\times 100}{L}$ is clearly shown as the season advances—an increase which is indicative of a distinct differential growth, resulting in the rapid increase in the relative size of the eggs as maturity approaches.

In May there is comparatively little difference in the relative size of the eggs of the mature fish and those of the immature fish. The value of the ratio for immature fish is very close to 2.0, and in May the ratio for mature fish is only about 2.6. During the season, however, the value of the ratio in the case of the maturing fish steadily increases until it is nearly three times as large as that for the immature fish. Evidently the differential growth of the eggs, which takes place during the last year, has not progressed far by May. Scale examinations show that the new growth of the year, if apparent at all, is at this time just beginning to show as a distinct band of wider rings at the margins of the scales. (See figs. 38, 39, and 40.) It seems altogether probable that the differential growth of the eggs is begun simultaneously with the onset of the growth period of the last year.

Another disturbing factor, which undoubtedly makes the accurate determination of the relative maturity from the size of the eggs more difficult, is the fact that the various collections contain a mixture of races, which, as has already been mentioned, have not been segregated, and it is known that there is considerable variation among different races in the size of the fully mature eggs.

In determining the relative maturity it has been found necessary to compare the size of the eggs of the fish taken in the ocean with the size of the eggs of the undoubtedly mature fish taken in the river at about the same time. Moreover, it has been found necessary to consider the entire distribution of egg sizes as exhibited in each collection in determining whether any particular group of fish was mature or immature. The tables have been carefully scrutinized and the size of the eggs in the particular group under consideration compared with the size of the eggs of the other fish taken in the same collection. If necessary, comparison has also been made with the size of the eggs of the undoubtedly mature fish taken in the river. In making these comparisons, not only the mean, but the range of the distribution as well, has been kept in mind. If a frequency distribution of egg sizes was found to be unimodal, the position of the mode and the extent of the dispersion were considered in relation to the position of the mode and the dispersion of other groups—especially those known to be mature. If the given distribution were bimodal or multimodal, the position of each of the modes and the distribution of individuals about these modes has been considered separately and compared with the mode and dispersion of other groups. It has proved impracticable to publish all of the detailed tables, but representative examples will be found on pages 81 to 88. The interpretations of the degrees of maturity have all been made through a study of such detailed tables.

In this study the logarithms of the observed egg diameters instead of the actual measurements have been tabulated and plotted. This has been done as a simple mechanical means of reducing all measurements to a strictly proportional basis. As has already been stated, it was thought during the early stages of the investigation that the egg size would indicate whether the immature fish were destined to mature during the year following their capture or not for two or more years. With this in mind it seemed essential to emphasize not the actual but the proportional variations, since a difference that would be relatively insignificant in the case of the larger eggs might be decidedly significant in the case of smaller eggs. For example, a difference of 0.5 mm. in eggs averaging 7 mm. in diameter would be of no great significance, while with eggs averaging only 0.7 mm. the same difference might be of decided importance. Therefore the logarithms of all measurements were found and the tables prepared from them. Although the final results of the study do not entirely justify the use of this method, the labor involved in retabulating the data, recalculating the constants, and redrawing the graphs is so great that it has not been attempted, particularly in view of the fact that such modification would in no way affect the conclusions that have been drawn. If it be remembered that this use of logarithms is only a means for showing *percentage* variation rather than *actual* variation in the size of the eggs, any confusion will be avoided.[2]

The tables and text figures have been arranged with class intervals of 0.02 in the logarithm of the diameter of the eggs. This is the same as saying that the mid-value of each class has been made 4.713 per cent greater than the mid-value of the next preceding class.

If the variations in the sizes of the eggs are such that the relative maturity of the fish can be determined from their study, several consequences will naturally follow, which may be used as criteria in determining the validity of the method. First, it must be possible to separate the fish taken in the ocean into at least two groups on the basis of the size of the eggs—one group corresponding approximately to the undoubtedly mature fish taken in the stream, and the other group characterized by distinctly smaller eggs and composed of fish that would not mature during the year in which they were taken. A comparison of almost any of the tables on pages 81 to 88, which show the variations in the size of the eggs of fish taken in the ocean, with a similar table of fish taken within the river at about the same time, will show that this is the case. One such example is shown in Figure 2, which shows the distribution of egg sizes in a collection made just outside the Columbia River, July 28, 1919, and also the similar distribution in a collection made inside, at Warrendale, Oreg., on July 16, 1919.

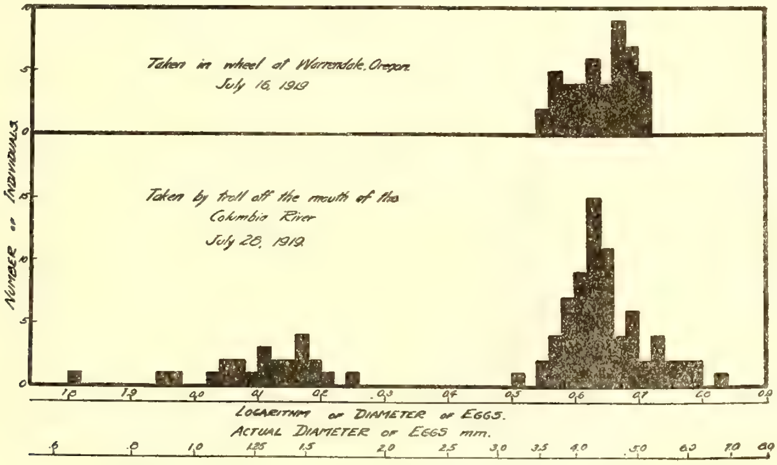

FIG. 2.—Distribution of egg sizes in two typical collections, one containing only mature fish and the other both mature and immature specimens

Figure 2 shows clearly that the fish taken outside the mouth of the river are sharply separated into two main groups—one with larger eggs, which closely agree in size with the fish taken inside the river at Warrendale and which are undoubtedly mature. There can be no question that the fish with the smaller eggs would not have matured during the year in which they were caught. The details of the distribution of egg sizes among the various age groups in these two collections can be seen by referring to Tables 17 and 18, on page 81.

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[2] For the benefit of those unfamiliar with the use of logarithms it may be stated that the logarithm of 1 is 0, that the logarithms of all values lying between 1 and 10 are less than 1 and greater than 0, and that the logarithms of all values lying between 1 and 0.1 lie between 0 and −1. The logarithms of values intermediate between 1 and 10 appear, therefore, as simple decimal fractions. Those of values intermediate between 0.1 and 1 are customarily shown as a decimal fraction preceded by the figure 1 over which is placed the minus sign, thus: $\bar{1}$. The logarithm of 0.9 is therefore written $\bar{1}.9542$ and the logarithm of 1.1 is written 0.0414. It is also customary to abbreviate the phrase "logarithm of" to "log"; thus, in this paper "log D" has frequently been used to indicate "the logarithm of the diameter."

Secondly, if it be true that the variations in egg size form a valid criterion of the degree of maturity, it should be found that among the fish taken in the ocean some of the age groups will contain both individuals with large eggs and others with small eggs. Those with large eggs are destined to mature during the year in which they were caught and those with small eggs would not have matured for at least one more year. This condition will inevitably result from the fact that the fish do not all mature at the same age. Considering the fish of a single age group, say three years with ocean nuclei, which may be found together in the ocean, some of them will mature during the year as 3-year fish while others will not mature for another year, as 4-year fish. If the size of the eggs forms such a criterion as is claimed, it should be possible to segregate these two categories on the basis of egg sizes. It has been found possible to do this more or less clearly in a number of the collections that have been studied. For example, in Table 18 (p. 81) it may be seen that individuals with large eggs (maturing) and those with smaller eggs (immature) are to be found among the fish in their third year with scales having nuclei of the ocean type. The same thing is true of the fish in their fourth year with scales having nuclei of the stream type, given in the same table. Similarly, in the collection at Monterey (June 19 to 21, 1918) the 3-year fish with ocean nuclei are well separated into two groups on the basis of egg size (Table 25, p. 87). The frequency distribution in this last-mentioned collection is shown in Figure 3.

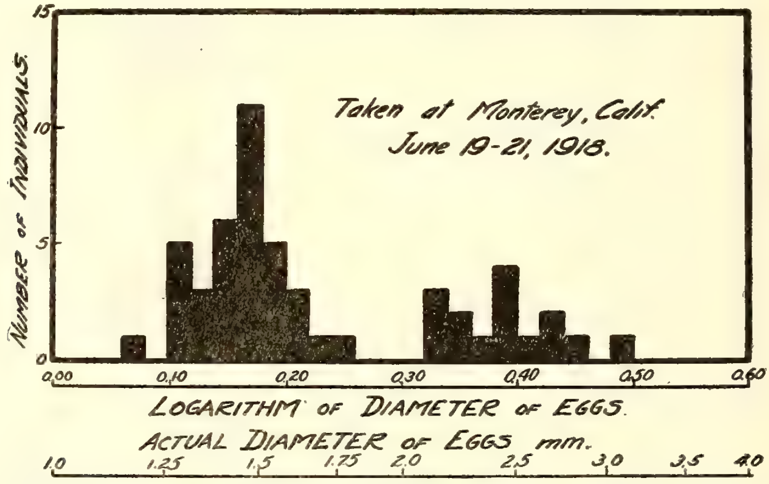

FIG. 3.—Distribution of egg sizes among females in their third year, ocean nuclei, taken at Monterey, June 19 to 21, 1918

CORRELATION BETWEEN SIZE OF EGGS AND SIZE OF FISH

A careful examination of the data has been made in order to determine to what extent the size of the eggs is correlated with the size of the fish, and, further, the extent to which this factor may tend to produce the observed differences in egg sizes.

A very definite positive correlation is found to exist between the size of the eggs and the size of the fish when fish of the same age group and the same degree of maturity are considered. The coefficient of correlation (*r*) has been computed for two typical distributions—one of mature and the other of immature fish. Table 2 shows the correlation between the size of fish and the size of eggs in 66 females in their fourth year, ocean nuclei, which were taken by troll off the mouth of the Columbia River, August 13, 1919. There are obviously two distinct groups represented in this tabulation, which are readily distinguishable on the basis of egg size. One group of 63 individuals, in which the logarithm of the diameter of the eggs is greater than 0.55, and another containing only three individuals, in which the logarithm is less then 0.35. The group with the larger eggs is mature and the coefficient of correlation between size of eggs and length of fish was found to be 0.6210 ± 0.0531, a high positive correlation.

Table 2.—*Chinook salmon taken by troll off the mouth of the Columbia River, August 13, 1919*

Females in their fourth year and which migrated as fry (scales with ocean nuclei) tabulated to show correlation between length and size of eggs

Logarithms of diameter of eggs (mid-value of class)	Centimeter length (mid-value of class)																Total
	77	79	81	83	85	87	89	91	93	95	97	99	101	103	105	107	
0.29			1	1													2
.33*								1									1
.57**		1				1											2
.59	1								1								2
.61	1																1
.63					1			1	1								3
.65	1							2	2	1	1						7
.67		1	1	1		1					2						6
.69							1	1									2
.71										1	1						2
.73							1	4			1	1			1		8
.75		1		1						1						1	4
.77							1			2	2	2					7
.79									2		3	1	2	1	1	1	11
.81									2		1	1	1	1			6
.83											1		1				2
Total	3	3	2	3	1	2	3	9	8	5	12	5	4	2	2	2	66

Note.—In this and all other tables of this report an asterisk (*) has been used to mark a break in the continuity of the table. It indicates that one or more classes have been omitted from the natural sequence just preceding the class marked. A double asterisk (**) is used to mark such breaks as are of particular significance.

The coefficient of correlation between size of eggs and size of fish has likewise been determined for a group of 36 immature females in their third year, ocean nuclei, taken in Monterey Bay, June 19 to 21, 1918. The data showing the distribution according to size of eggs and length of fish of all the females of this age group contained in the collections are given in Table 3. Two distinct groups, which are well separated on the basis of egg size but overlap almost completely in length, are also shown in this tabulation. The coefficient of correlation for the immature group is 0.7680 ± 0.0461.

TABLE 3.—*Chinook salmon taken by troll in Monterey Bay, Calif., June 19 to 21, 1918*

Females in third year, and which migrated as fry (scales with ocean nuclei), tabulated to show correlation between size of fish and size of eggs

Logarithm of diameter of eggs (mid-value of class)	Centimeter length (mid-value of class)																	Total	
	57	59	61	63	65	67	69	71	73	75	77	79	81	83	85	87	89		
0.07	1																	1	Group 1 (36 individuals).
.11*		1			1	1	2											5	
.13				1		2												3	
.15				1		3		1		1								6	
.17					1	3	1	2	1	2	1							11	
.19							1	1		2	1							5	
.21										1	2							3	
.23													1					1	
.25												1						1	
.33**											1	1	1					3	Group 2 (15 individuals).
.35										1			1					2	
.37									1									1	
.39								1		1	1		1					4	
.41														1				1	
.43												1		1				2	
.45													1					1	
.49*														1				1	
Total	1	1		2	2	9	4	5	2	8	6	3	5	3				51	
Group 1	1	1		2	2	9	4	4	1	6	4	1	1					36	
Group 2								1	1	2	2	2	4	3				15	

These examples indicate clearly that within a single category (that is, among females of a similar degree of maturity and of the same age group) the size of the eggs is dependent to a considerable extent upon the size of the fish. The regression coefficients have been calculated for the two groups for which the coefficients of correlation were determined. From these it was found that in the first group (mature fish taken off the Columbia River in August) the logarithm of the diameter of the eggs was, on the average, increased by 0.005850 for each increase of 1 cm. in the length of the fish. In the second group (immature fish taken at Monterey in June) an increase of 1 cm. in the length of the fish was accompanied, on the average, by an increase of 0.005535 in the logarithm of the diameter of the eggs.

It may readily be seen, however, from an examination of Tables 2 and 3, that the groups distinguished as mature and immature are sharply and widely separated on the basis of egg sizes but overlap almost completely in so far as length is concerned. Within each group there is the distinct tendency for the larger fish to have larger eggs, but this is quite inadequate to account for the greater difference observed between the mature and immature groups. These can only be explained as the result of the differential growth of the eggs during the last year.

FISH TAKEN IN THE COLUMBIA RIVER AND IN THE OCEAN OFF THE MOUTH OF THE RIVER

In discussing the various features of the life history, which will be treated in this paper, the data on the fish from the Columbia River, from near Fort Bragg and Point Reyes on the northern coast of California, and from Monterey Bay will be handled separately. Each age group will also be given separate consideration. The oldest fish will be treated first, since the results of their study will aid in interpreting the data from the younger age groups.

RELATIVE MATURITY OF CHINOOK SALMON TAKEN IN THE OCEAN

It has been shown above that the determination of the degree of maturity is accomplished primarily by comparing the distribution of the egg sizes of a group of fish with the similar distribution of fish known to be mature. It has been pointed out that the size of the eggs changes during the season; that there are differences in the size of eggs of fish of different ages, due to the difference in the size of the fish; and also there are racial differences in the size of the eggs. It is obvious that these factors will make it impossible to draw a sharp line of distinction, which will hold good throughout the season, between the size of the eggs of mature and immature fish, and that the determination of the relative maturity of the fish taken in the ocean must depend upon a comparison of the distribution of egg sizes in the various age groups with the distribution of egg sizes of unquestionably mature fish taken in the river at about the same time of the year. This has been done in the determination of relative maturity given below.

FISH IN THEIR SIXTH YEAR, OCEAN NUCLEI

Only two females of this age group were taken in the collection studied. One was taken on July 28, 1919, and the other September 18 or 19, 1919. Both were undoubtedly mature. The logarithm of the diameter of the eggs (log *D*) was 0.69 in the first specimen and 0.77 in the second. No fish of this age group appear in the collections taken inside the river near these dates, but four specimens are found in a collection made June 24 and 25, 1919, and three in one made July 3. The average log *D* in these collections was, respectively, 0.55 and 0.657. The maximum age attained by the chinooks of the Columbia River is 6 years, and comparatively few fish of this age are found. It is, therefore, quite to be expected that any fish of this age group which might be taken in the ocean would be maturing.

FISH IN THEIR FIFTH YEAR, OCEAN NUCLEI

As has just been indicated, very few fish with ocean nuclei older than 5 years are found in the Columbia River run. It was, therefore, to be expected that nearly, if not quite all, of the fish of this age group which are taken outside would be maturing, and such was found to be the case. No immature fish of this age group were found. Figure 4 shows the average log *D* for the collections of fish taken outside and also for those taken inside throughout the season. The figure shows clearly that there are only negligible differences in the sizes of the eggs of the fish taken in the two localities.

FISH IN THEIR FOURTH YEAR, OCEAN NUCLEI

The determination of the relative maturity of the fish of this age group has proved more difficult and the results are less satisfactory than with any other category. The number of fish belonging to this age group, which were taken in the ocean and which were with certainty immature, is small. There must, however, be a considerable proportion of the 4-year fish with ocean nuclei that do not mature during their fourth year, since there is a rather high percentage of fish in their fifth year, with ocean nuclei, found both in the ocean and within the stream. No satisfactory explanation of this can be given, although the possibility of some sort of a selective migration naturally suggests itself. Figure 5 shows the distribution of egg sizes for this age group during the season, and it may readily be seen that, with the exception of the groups marked by a double circle, the range of egg sizes shown by the fish taken outside is quite comparable with the range shown by those taken inside the river. The groups indicated by a double circle are those that may be considered as immature, although the interpretation, especially in the case of those collections made during May, is somewhat doubtful.

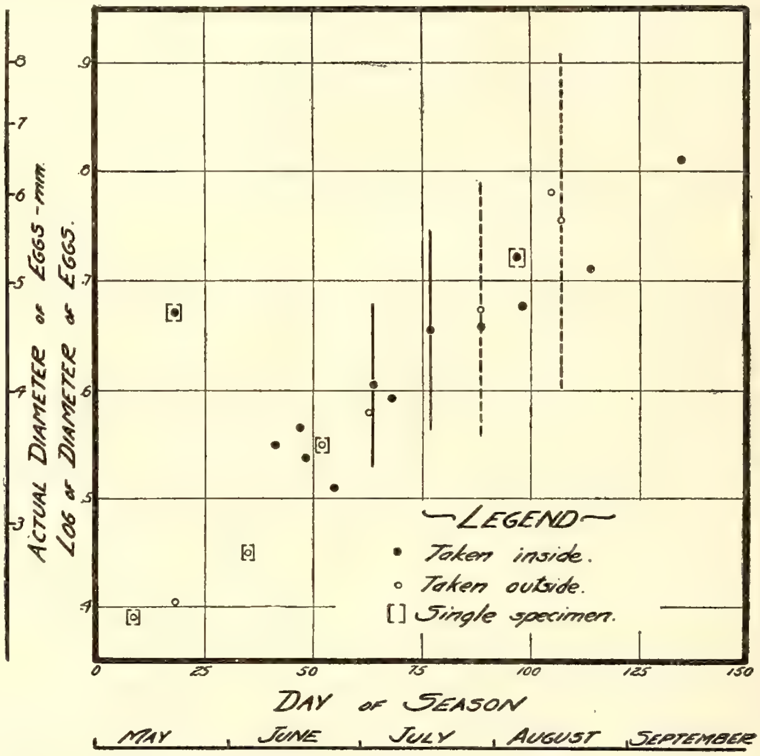

FIG. 4.—Sizes of eggs of females in their fifth year, ocean nuclei, from the Columbia River and the ocean off the mouth of the river. In this and other similar illustrations the average size of the eggs is indicated by the circles or dots; the vertical lines extending from these points show the limits of twice the standard deviation (± 2 σ). Ninety-five per cent of the cases will fall within the upper and lower limits indicated by these lines. The standard deviation has, with a few exceptions, been calculated only for those cases in which at least 20 individuals of the particular age group in question were contained in the collection

A correlation table has been prepared (Table 4), giving the sizes of the eggs found in the fish of this age group contained in a collection of troll fish taken off the mouth of the Columbia River, May 17 and 18, 1920. Reference to this table will show that the fish are quite distinctly separated into two groups on the basis of egg sizes. The log *D* of one group is greater than 0.30, averaging 0.4254, and of the other group is less, averaging 0.2486. The modes of the two distributions are distinct, and it seems probable that two categories are represented—one of mature and the other of immature fish. This interpretation is further indicated by the fact, apparent from Figure 5, that the size of the smaller eggs agrees with the size of eggs in other later collections, in which there is no question as to the correct interpretation. Reference to Figure 9 shows also that these small eggs are approximately the same size as those of the immature fish taken at the same time, which were in their fourth year, stream nuclei—a group fairly comparable with the one under discussion. The distribution of egg sizes in the case of these 4-year fish with stream nuclei is similar to that of the 4-year fish with ocean nuclei in that it does not seem sharply to separate the two groups of mature and immature fish. The factor $\frac{D \times 100}{L}$, described above and illustrated in Table 1, has been calculated for that

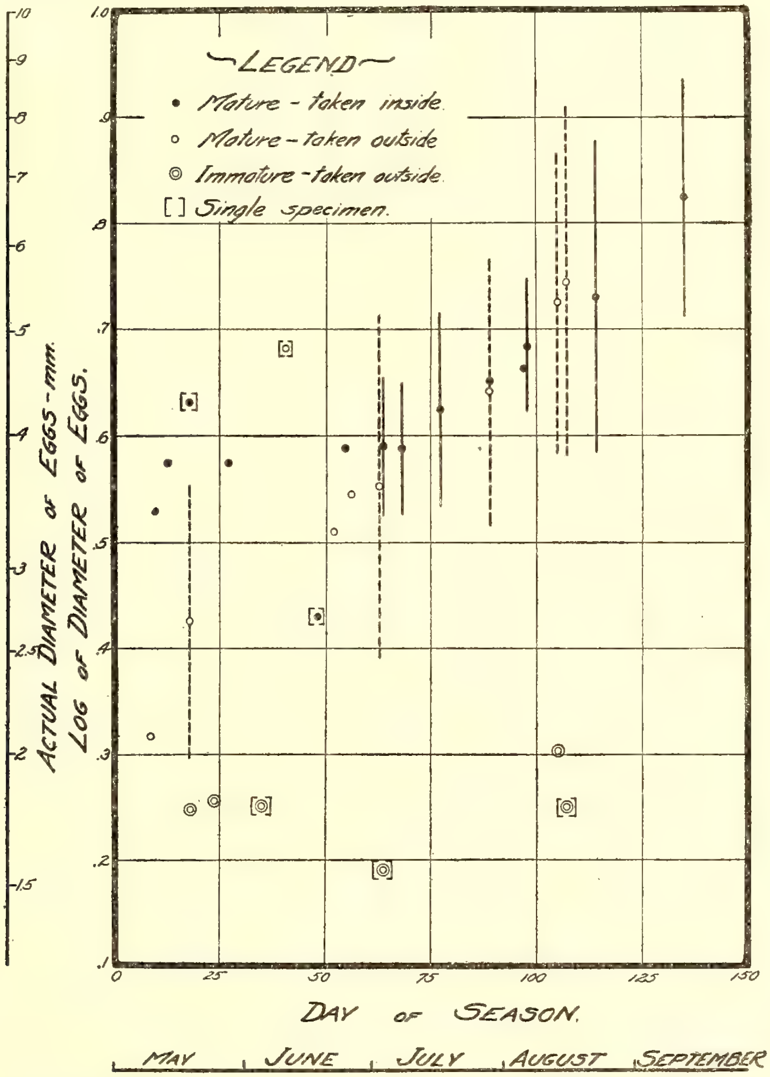

FIG. 5.—Sizes of eggs of females in their fourth year, ocean nuclei. Columbia River and the ocean off the mouth of the Columbia

group of 4-year fish with ocean nuclei that had the smaller eggs, and was found to be 2.24.[3] This is somewhat larger than is characteristic of immature fish (about 2.0), but it is nearer this figure than that which is characteristic of mature fish taken in May (2.6).

Table 4.—*Chinook salmon taken by troll off the mouth of the Columbia River, May 17 and 18, 1920*

[Females in their fourth year, ocean nuclei, tabulated to show correlation between length and size of eggs]

Logarithms of diameter of eggs (mid-value of class)	Centimeter length (mid-value of class)														Total
	73	75	77	79	81	83	85	87	89	91	93	95	97	99	
0.21		1													1
.23		1	1		1	1									4
.25	1				3	1									5
.27			2			1									3
.29					1										1
.33**								1							1
.35					1		1								2
.37			1		1		1		2						5
.39					2										2
.41			1												1
.43								1	1						2
.45						1	1					1			3
.47								2							2
.49							1								1
.55*			1									1	1		3
Total	1	2	6		9	4	4	4	3			2	1		36

The relatively slight differences noted between the size of the eggs of the mature and those of the immature fish in this collection are probably associated with the fact that the collection was made in 1920, while most of the collections that have been made the basis for this study were made in 1919. It is not improbable that the differential growth of the eggs, which takes place during the last year (and which has been shown to be mainly responsible for the observed difference in the sizes of the eggs of mature and immature fish), may begin at different times in different years. It should also be noted that the fish taken in the ocean during 1920, which were available for study, were selected, very few being under 8 pounds in weight. Laws passed by the Washington and Oregon Legislatures prevented the sale of immature salmon under this weight, so that few of the smaller fish found their way to the canneries. This factor alone, by tending toward a selection of gear that would take the larger fish, might well be responsible for the difficulty encountered in determining the relative maturity of the fish found in this collection.

In most of the other collections no particular difficulty has been encountered in determining the relative maturity, but the percentage of immature fish is, as has already been mentioned, much lower than would naturally be expected. Figure 30 shows a scale from one of the immature fish of this age group taken on August 13, 1919, and Figure 31 a scale from one of the mature fish taken at the same time.

FISH IN THEIR THIRD YEAR, OCEAN NUCLEI

The distribution of egg sizes during the season for the fish that are in their third year, with ocean nuclei, is shown in Figure 6. The difficulties encountered in the interpretation of the data in the case of the 4-year fish with ocean nuclei are entirely lacking here. Two distinct distributions are clearly shown. In one the eggs are small, the average log D being in every case less than 0.20, and the increase in size observed as the season advances is very slight. It has already been shown

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[3] Average log $D=0.2485$. Geometrical mean of the diameters=1.772 mm. Average length=79 cm. $\frac{177.2}{79}=2.24$.

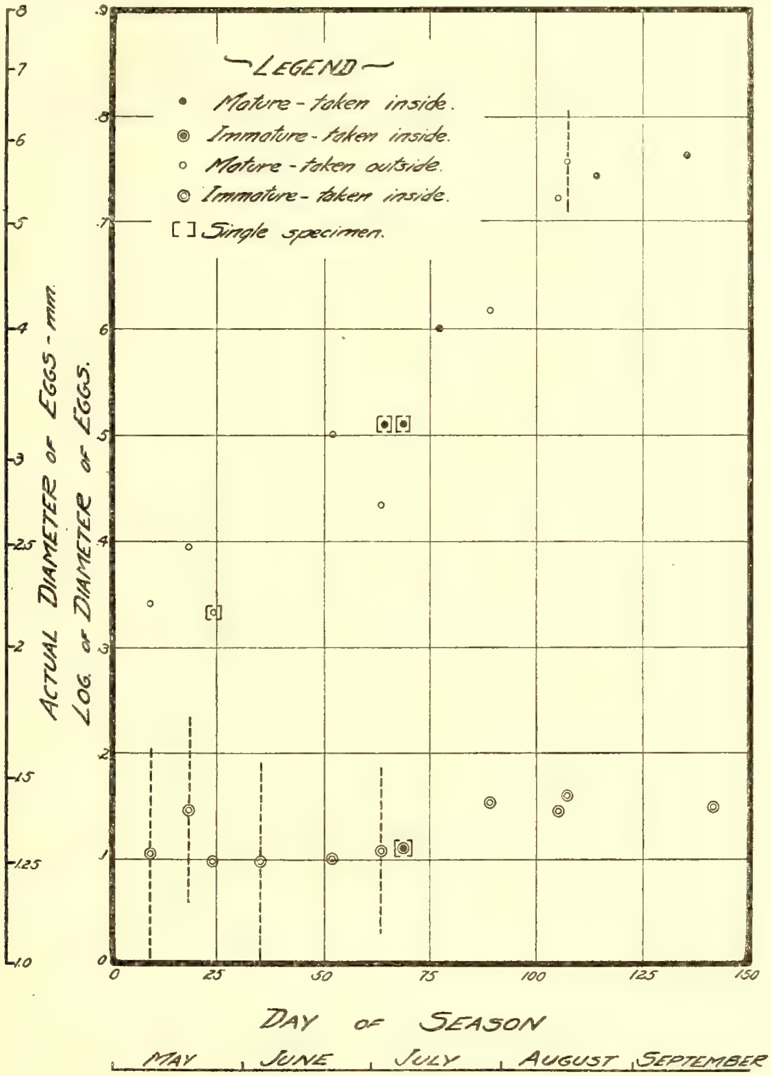

FIG. 6.—Sizes of eggs of females in their third year, ocean nuclei. Columbia River and the ocean off the mouth of the Columbia

in Table 1 that the factor $\frac{D \times 100}{L}$, for fish of this age group contained in several of the larger and typical collections, is close to 2, which is characteristic of other groups of undoubtedly immature fish.

In the other distribution the eggs are distinctly larger, the log D ranging from about 0.34 at the beginning of the season to about 0.80 by the end of the season. This increase in size during the season is conspicuous and is in marked contrast to the condition observed in the group of immature fish. So far as the available data show, the segregation of the fish of this age group into mature and immature groups may be accomplished with very satisfactory accuracy by means of a study of the egg sizes. The percentage of mature and immature fish taken at different times during the season is treated on page 40 ff. Figure 28 shows a scale from one of the immature fish of this age group, which was taken on July 2, and Figure 29 one of the mature fish taken on the same date.

It will be noticed in the collection made inside the river on July 7, 1919, that one immature fish of this age group was taken. It will presently be shown that there were other immature fish taken at the same time which belonged to other age groups—2-year fish with ocean nuclei and 3-year fish with stream nuclei. The explanation of this occurrence and other associated facts is interesting in its possible bearing on the habits of the chinook salmon.

These immature fish observed inside the river were taken by seine on Sand Island, a low, level, sandy island several miles in length and about 1 mile in width, which is situated in the estuary of the Columbia River, only a mile or so inside the mouth of the river. The seining grounds are toward the upper end of the island, approximately 5 miles from the river's mouth. On the Washington side of Sand Island is Baker Bay, a broad, shallow stretch of water in which are situated most of the salmon traps in use on the Columbia River—about 200 in number. Under ordinary circumstances the water of this lower part of the Columbia estuary is fresh or only slightly brackish, depending upon the tides and the flow of the river. At the time of the "spring" tides, however, especially when the river is at a low stage, the lower part of the estuary, up for a distance of several miles, becomes very brackish, approximating the salinity of pure sea water. On such occasions it frequently happens that small, immature fish are taken, both in the seines operating on Sand Island and in the traps in Baker Bay. It is generally believed among the fishermen of the lower Columbia River, and some statistical evidence is available which would indicate that the belief is well founded, that the salmon enter the river in greater numbers on the spring than on the neap tides. Apparently the immature fish to some extent join those that are maturing in a general movement into the river on these high tides, but do not pass beyond the upper limit of the approximately pure sea water. It is at these times that immature fish are taken on Sand Island and in Baker Bay. Presumably the immature fish return to the ocean again as the water freshens with the receding of the tide, while the mature individuals remain, in large measure, to continue their spawning migration.

In this connection it is interesting to note that the stomachs of the immature fish thus taken inside the river are frequently filled with food, usually in an advanced stage of digestion. This is in contrast to the condition in the mature fish, the stomachs of which have never been observed to contain any food.[4]

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[4] The writer has described (Rich, 1921) an instance, apparently unique, in which the stomachs of mature salmon taken in fresh water contained food. In the case described chinook salmon were found feeding on eulachon (*Thaleichthys pacificus*) in the Cowlitz River, a tributary of the Columbia, some 70 miles above the ocean.

FISH IN THEIR SECOND YEAR, OCEAN NUCLEI

All of the females of this age group taken in the ocean have been found to be immature. This was to be expected, since it is known that no mature females of this age are found among the spawning runs within the river. Figure 7 shows the distribution of egg sizes during the season. Comparison with Figure 6, which shows the size of eggs of the 3-year fish with ocean nuclei, will show that the eggs are distinctly smaller in the case of the 2-year-old fish. This would be expected from the fact, previously demonstrated, that the size of the eggs is correlated to a high degree with the size of the fish.

The question arises as to the relative maturity of these 2-year-old fish as compared to those that are 3 years old. It has been shown above that the method used for determining relative maturity is inadequate to differentiate between degrees of immaturity, although it is, in most cases, an entirely adequate and reliable means for distinguishing between fish that will mature during the year in which they are taken and those that will not mature for at least one more year. Although it is impossible to establish the fact with certainty, the probabilities are all in favor of considering the 2-year fish as, on the whole, one year further from maturity than the 3-year fish taken at the same time. Certain obvious possibilities for error are inherent in such a treatment, especially when comparatively few data are available, as in the present case, but it is felt that the picture presented by this means will be much nearer the true state of affairs than can be arrived at by any other method. This allowance will, therefore, be made in the later discussion of the percentages of mature and immature fish taken at different times of the year.

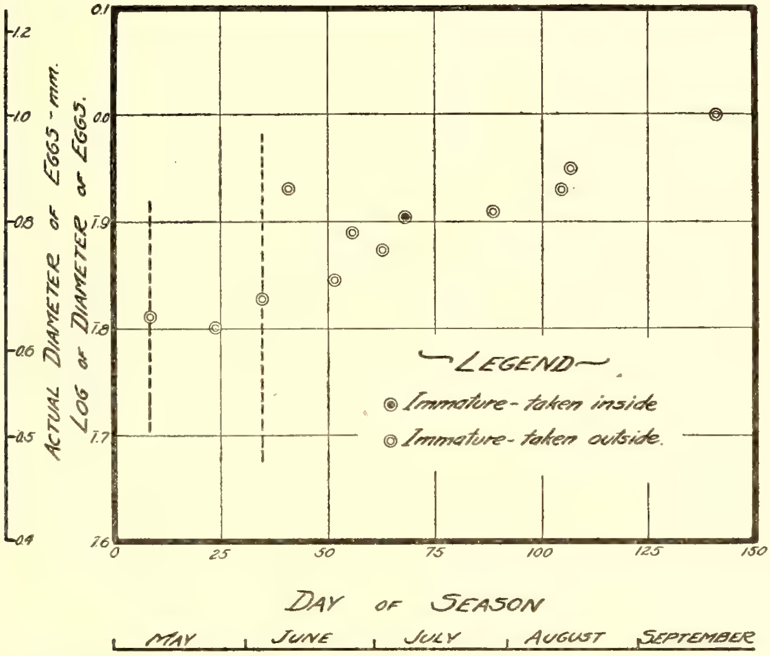

FIG. 7.—Sizes of eggs of females in their second year, ocean nuclei. Columbia River and the ocean off the mouth of the Columbia

FISH IN THEIR SIXTH YEAR, STREAM NUCLEI

Only three specimens of this age group were found among the troll fish included in this study. Two of these were taken May 8 to 10, 1919, and one August 13 to 17, 1918. In the discussion of the 6-year-old fish with ocean nuclei, it was mentioned that 6 years is the maximum age of chinook salmon in the Columbia River, and it follows that fish of this age could only be mature. The size of the eggs indicated beyond question that such was the case. The eggs of the two specimens taken in May had an average log D of 0.58, and the log D of the specimen taken in August was 0.75. The log D of the fish of this age group taken inside the river, of which there were 7 specimens, ranged from 0.51 to 0.75.

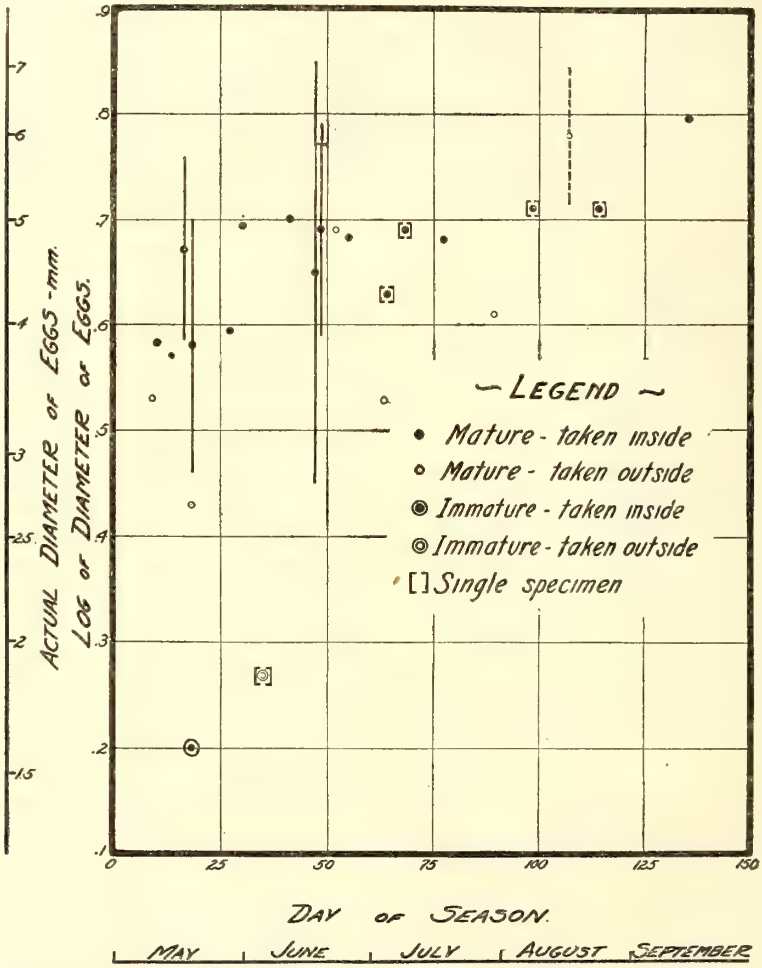

FIG. 8.—Sizes of eggs of females in their fifth year, stream nuclei. Columbia River and the ocean off the mouth of the Columbia]

FISH IN THEIR FIFTH YEAR, STREAM NUCLEI

Figure 8 shows the distribution of egg sizes for fish of this age group during the season. Only three immature fish were found. Two of these were taken in the lower part of the Columbia River estuary, May 17 and 18, 1920, one in a trap in Baker Bay, and another by gill net. The other immature fish was taken by troll, June 4, 1919, The figure shows how distinctly these immature specimens are separated from the maturing fish on the basis of egg size. There can be no doubt of their immaturity. Figure 38 shows a scale of one of the immature fish taken inside the river in May, and Figure 39 one from a mature fish of the same age group taken at the same time.

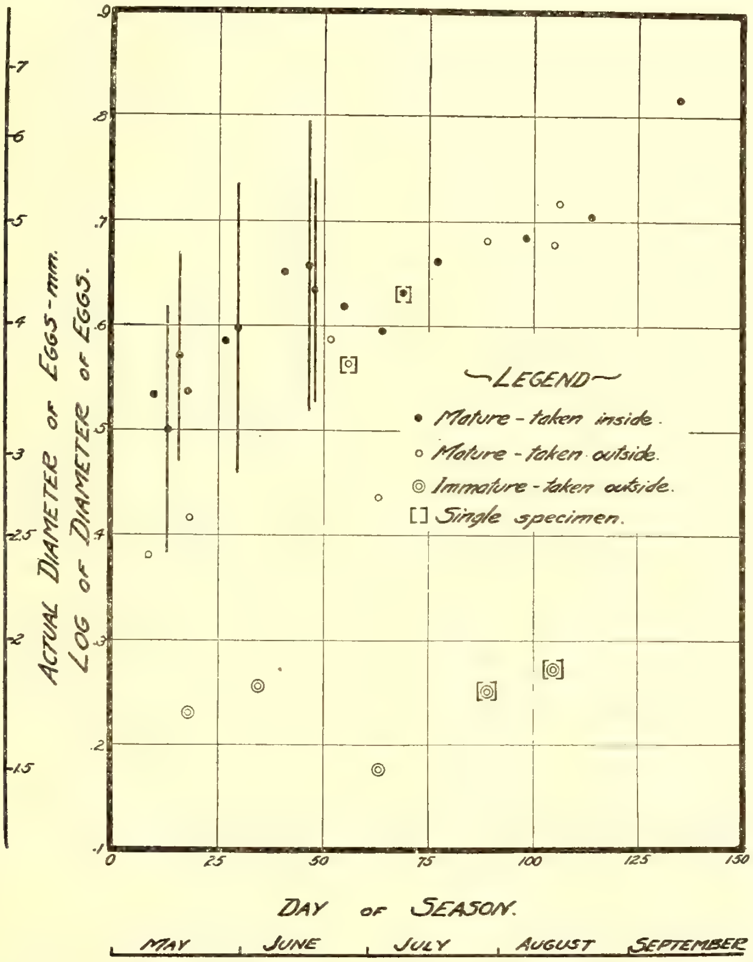

FIG. 9.—Sizes of eggs of females in their fourth year, stream nuclei. Columbia River and the ocean off the mouth of the Columbia

FISH IN THEIR FOURTH YEAR, STREAM NUCLEI

The distribution of egg sizes found among the females of this age group are shown in Figure 9. Two distinct groups are apparent, in one of which the average log D is less than 0.30. In the other group, the log D ranges from 0.40 or 0.50 in the early part of the season and to about 0.80 at the end of the season. The first group is composed of immature individuals and the second of those that are maturing. Figures 36 and 37 show scales of immature and mature fish, respectively, taken by troll on July 28, 1919.

FISH IN THEIR THIRD YEAR, STREAM NUCLEI

The fish of this age group resemble the 2-year-old fish with ocean nuclei in that mature females have never been reported. None of these fish taken outside was mature, as is apparent from Figure 10. The question of the percentages of these fish that will mature during the following year as 4-year fish, and during the second subsequent year as 5-year fish, arises here as in the case of the 2-year fish with ocean nuclei. As in the case previously considered, it seems probable that these 3-year fish with stream nuclei are, on the whole, one year further from maturity than those in their fourth year. Two-thirds of the 4-year fish with stream nuclei were mature, so that it appears probable that approximately two-thirds of these 3-year fish with stream nuclei will mature during the following year and one-third during the second year following. A very few will not mature until they are in their sixth year.

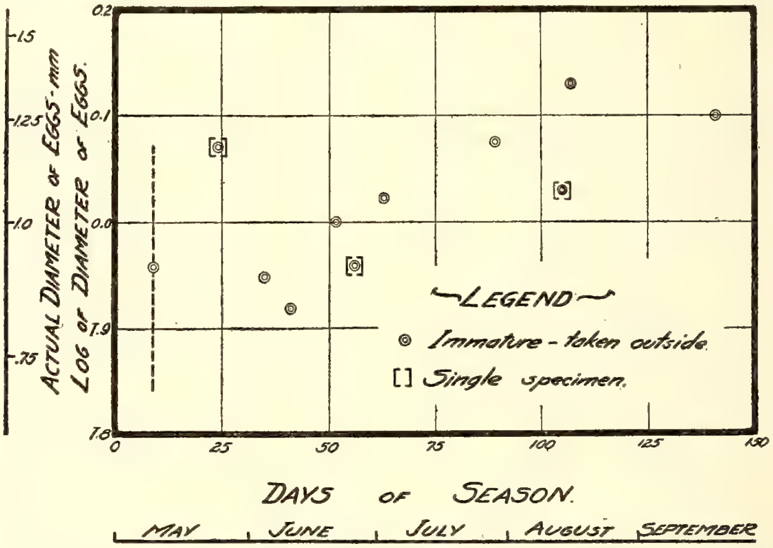

FIG. 10.—Sizes of eggs of females in their third year, stream nuclei. Columbia River and the ocean off the mouth of the Columbia

FISH IN THEIR SECOND YEAR, STREAM NUCLEI

No females of this age group were found in any of the collections, although a very few males were discovered. One was taken inside and three outside. Among these three, however, two were contained in a special collection, made in 1914, of fish selected for their small size—the "grilse." Mature males of this age group are extremely rare in the Columbia River and apparently are seldom taken by troll. In so far as their maturity is concerned, it seems fair to assume that they will mature one year later than the 3-year fish with stream nuclei and two years later than the 4-year fish.

In the preceding discussion of the various age groups, no attempt has been made to show the percentage of mature and immature fish in each, nor the percentage which the immature fish formed of the total number in the different collections. These data have been compiled in separate tables for ease in making comparisons. Table 5 shows, for each collection of fish taken inside the river, the percentages of the total number of females which are composed of the mature and immature fish of the different age groups. Table 6 gives similar data for the collections of fish caught in the ocean. A discussion of the composition of the entire collections as regards age groups will be given later, but attention is first directed to a discussion of the age groups most commonly represented among the immature fish.

AGE OF IMMATURE FISH

Reference to Table 5 shows, as would be expected, that very few immature fish are taken inside the river. It has already been explained (page 34) that a few immature fish are occasionally taken in the lower part of the Columbia River estuary. The collections of May 17 and 18, July 3, and July 7 were all made in this part of the river and are the only ones to contain immature fish. Such immature fish as were taken belong to the 2 and 3 year groups with ocean nuclei and to 3 and 5 year fish with stream nuclei.

Table 5.—*Percentages of females of different age groups and different degrees of maturity taken in the river at different times during the season* [1]

Date	Ocean nuclei in—						Stream nuclei in—				
	Second year	Third year		Fourth year	Fifth year	Sixth year	Third year	Fourth year	Fifth year		Sixth year
	I.	I.	M.	M.	M.	M.	I.	M.	I.	M.	M.
May 10				4.5				72.8		22.7	
May 13				11.1				62.2		26.7	
May 16								77.8		22.2	
May 17 and 18				2.9	2.9			8.8	5.9	79.5	
May 27				44.5				14.8		33.4	7.4
May 30 and 31								84.0		16.0	
June 10					45.5			18.2		36.3	
June 16					8.0	2.0		52.0		36.0	2.0
June 16 and 17				2.1	20.8			35.4		41.7	
June 24 and 25				40.8	11.1	14.8		18.5		11.1	3.7
July 3			2.0	47.0	33.3	5.9	2.0	7.8		2.0	
July 7	12.2	2.4	2.4	48.8	19.5		9.8	2.4		2.4	
July 16			4.3	41.3	39.2			8.7		4.3	2.2
July 28				34.8	65.2						
Aug. 5				80.0	20.0						
Aug. 6				55.3	34.2			7.9		2.6	
Aug. 22			19.5	61.1	7.3			7.3		2.4	2.4
Sept. 12			16.7	57.2	9.5			7.1		7.1	2.4

[1] The initials I. and M. stand for immature and mature, respectively.

Among the fish taken in the ocean (Table 6), it is seen that by far the greater part of the immature fish are in their third year, with ocean nuclei. Fish in their second year, ocean nuclei, are the next most important component. Fish in their third year, stream nuclei, come next in importance. In addition to these age groups, which include the greater part of the immature fish taken, a few immature fish in their fourth year with ocean nuclei, fourth year with stream nuclei, and fifth year with stream nuclei, are taken.

TABLE 6.—*Percentages of females of different age groups and different degrees of maturity taken in the ocean at different times during the season* [1]

Date	Ocean nuclei in—							Stream nuclei in—					
	Second year	Third year		Fourth year		Fifth year	Sixth year	Third year	Fourth year		Fifth year		Sixth year
	I.	I.	M.	I.	M.	M.	M.	I.	I.	M.	I.	M.	M.
May 8 to 10	11. 5	60. 6	1. 2		10. 9	0. 6		10. 9		1. 2		1. 8	1. 2
May 18, 1920		29. 0	7. 5	13. 1	20. 5	12. 2			6. 5	5. 6		5. 6	
May 24	25. 0	43. 7	6. 3	18. 7				6. 3					
June 4	26. 4	47. 0		1. 5		1. 5		16. 2	5. 9		1. 5		
June 10	33. 3	33. 3			11. 1			22. 2					
June 21	19. 3	6. 5	6. 5		32. 3	3. 2		12. 9		16. 1		3. 2	
June 25	42. 8				28. 6			14. 3		14. 3			
July 2	14. 1	26. 3	5. 1	1. 0	22. 2	11. 1		7. 1	3. 0	7. 1		3. 0	
July 28	3. 1	13. 2	3. 1		50. 0	18. 4	1. 0	7. 1	1. 0	2. 0		1. 0	
Aug. 13	2. 1	6. 3	9. 5	3. 2	66. 4	4. 2		1. 0	1. 0	6. 3			
Aug. 13 to 17	4. 9	3. 9	20. 6	1. 0	18. 6	18. 6		1. 9		2. 9		26. 5	1. 0
Sept. 18 and 19	16. 7	58. 3					8. 3	16. 7					

[1] The initials I. and M. stand for immature and mature, respectively.

PERCENTAGES OF IMMATURE FISH AT DIFFERENT TIMES

The composition of the various collections as regards mature and immature fish is best shown in Tables 7 and 8, which give the percentages of mature and immature fish found in each collection taken inside and outside, respectively. In Table 8 is also given the estimated percentage of fish that would not mature for two or more years. This has been derived by assuming that in any one collection the 2-year fish with either ocean or stream nuclei would, the next year, show a similar percentage of mature and immature fish as did the 3-year fish with the same type of nucleus at the time the collection was made. As has been mentioned above, this assumption is not necessarily justified, but it is believed that the general results of the application of such an assumption will approximate more closely the true state of affairs than could otherwise be reached.

TABLE 7.—*Percentage of mature and immature females taken inside the river at different times during the season*

Date	Percentage		Date	Percentage	
	Immature	Mature		Immature	Mature
May 10		100	July 3	2	98
May 13		100	July 7	25	75
May 16		100	July 16		100
May 17 and 18	5	95	July 28		100
May 27		100			
May 30 and 31		100	Aug. 5		100
			Aug. 6		100
June 10		100	Aug. 22		100
June 16		100			
June 16 and 17		100	Sept. 12		100
June 24 and 25		100			

TABLE 8.—*Percentage of mature and immature females taken outside the river at different times during the season*

Date	Percentage due to mature during—			Total percentage of immature fish	Date	Percentage due to mature during—			Total percentage of immature fish
	Year taken (mature)	Next year	Second year			Year taken (mature)	Next year	Second year	
May 8 to 10	16. 9	71. 7	11. 3	83. 1	July 2	48. 5	37. 6	13. 9	51. 5
May 24	6. 3	71. 9	21. 8	93. 7	July 28	75. 5	19. 6	4. 9	24. 4
June 4	1. 5	55. 9	42. 6	98. 5	Aug. 13	86. 4	12. 7	. 9	13. 6
June 10	11. 1	55. 5	33. 3	88. 9	Aug. 13 to 17	88. 2	10. 9	. 8	11. 7
June 21	61. 3	29. 1	9. 6	38. 7					
June 25	42. 9	57. 1	----------	57. 1	Sept. 18 and 19	8. 3	75. 0	16. 7	91. 7

Reference to these tables shows that, with the exception again of the three collections made in the lower part of the Columbia estuary, the fish found inside the river are all mature. This is so obviously in accord with the familiar facts of the life history of the chinook salmon that it would be quite unnecessary to present the data given in Table 7 were it not for the unusual presence of immature fish in those collections made in the estuary and the desirability of presenting a table that may be compared with the similar table for the fish taken in the ocean. In the case of the fish taken outside the river, it is apparent that during May and the first half of June the percentage of immature fish is high. This percentage gradually falls during the latter part of June, July, and August, until by the middle of August only about 10 per cent of the fish taken outside are immature. The one collection made in September shows a high percentage of immature fish again. The number of fish included in this September collection is too small to be reliable (12), but it would not be surprising to find that at this time of year most of the fish taken outside are immature, since the height of the run of chinooks in the Columbia comes during August, and the result of the entrance into the river of most of the maturing fish would be to leave mainly immature fish outside. At the time these collections were made there was little outside fishing done during the fall months, so that it was impractical to gather adequate data.

The percentages of mature fish taken outside are shown in Figure 11. It is evident that, with the exception of the last record (that made in September), there is a fairly steady increase in the percentage of mature fish in the collections. The trend of this increase has been calculated, omitting the record for September and that for May 18, 1920, which has previously been shown to be unreliable for this purpose, and assuming that a straight line will approximate the most probable change in the percentage of mature fish taken. The trend has been calculated by the method of averages,[5] weighting the various points by the number of individuals contained in the collections that established the points. The trend, shown on the graph by the broken line, fits the later part of the data remarkably well, but it fails to fit accurately the data for the early part of the season. It is probable, however, that this trend represents the true tendency as accurately as could be done by any such generalization of the observed data. It is quite conclusively shown that during May less than 20 per cent of the fish taken in the ocean are mature; during July, between 50 and 75 per cent; and during August, between 75 and 90 per cent. It has already been mentioned that few data are available for September, but those that are available indicate a return to the low percentage of mature fish found during the early part of the season.

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[5] For a description of this method see Lipka, Graphical and Mechanical Computation, Wiley, 1918.

PERCENTAGES OF FISH MORE THAN ONE YEAR FROM MATURITY

Table 8 shows that the percentage of fish taken in the ocean which would not mature for two or more years is considerably less than the percentage that would mature in one more year. The data are not reliable enough to serve as a basis for definite conclusions, but in general it appears that fully two-thirds of the immature fish found in the commercial catch would reach maturity during the year following that in which they were taken. These percentages of immature and mature fish obviously do not represent the exact percentages of mature and immature fish that go to make up the schools in the ocean, but only the percentages as taken by the trollers. Undoubtedly there are much higher percentages of the younger age groups actually present outside the mouth of the river than would appear from this study of the catch. The taking of the small fish is relatively unprofitable to the fishermen if larger ones can be caught, and this would inevitably lead to such a selection of gear or of the locality in which the fishing is carried on as would make it possible to take more of the larger fish.

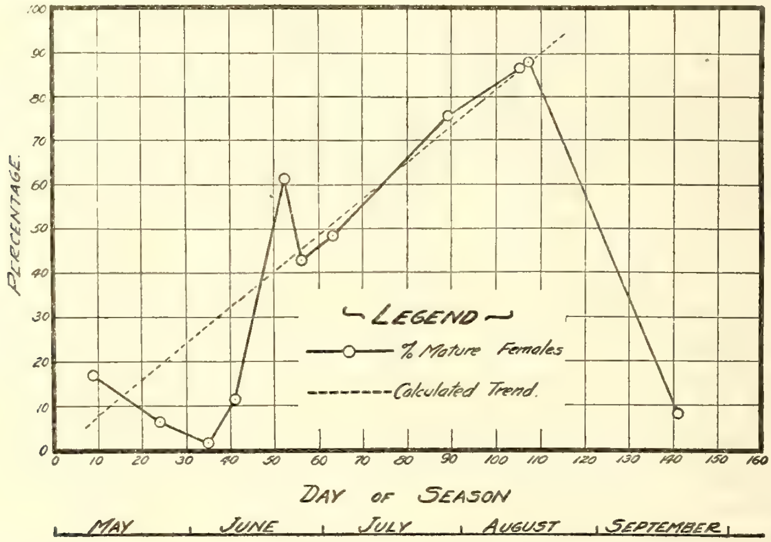

FIG. 11.—Percentage of mature fish taken off the mouth of the Columbia River (exclusive of the data from the collection made in 1920)

It should be noted that, in designating as "mature" fish taken in the ocean, it is not implied that such fish are ready to spawn or even to enter the river. The term is used merely to indicate that the individuals would mature and spawn during the year in which they were taken. There are many individuals especially during the early part of the season that are not ready to begin the spawning migration, even though they would have matured during the year in which they were taken. For instance, many of the fish with ocean nuclei captured during May and June, and which have been considered as mature, would, in all probability, not be ready to enter the river until August or September, and would be feeding and growing at a rapid rate during the interval. Gilbert has shown, in his paper on the salmon of Swiftsure Bank, that maturing cohoes taken at that point increased nearly 100 per cent in weight during July and August, just prior to their entry into fresh water for the purpose of spawning. On account of the range in the age at maturity of the chinook salmon, it is impossible to get as reliable figures for this species. It will presently be shown, however, that there is a distinct increase in length of the chinooks taken outside the mouth of the Columbia during the season. In the case of the 4-year fish with ocean nuclei—the age group that contains the greatest number of maturing individuals—the length increases from about 80 cm. at the opening of the season to over 90 cm. by the close of the summer season on August 25. Since the weights vary as the cubes of the linear dimensions, this increase in length indicated an increase of nearly 50 per cent in weight during the summer. At this rate a fish weighing 16 pounds at the opening of the season on May 1 would weigh 24 pounds by the end of August. The 3-year fish with ocean nuclei increase in length from about 60 cm. to about 75 cm. during the season. This indicates an increase of approximately 95 per cent in weight, a figure quite similar to that given by Gilbert for the cohoes, which are also 3-year fish.

In résumé, this inquiry into the relative maturity of the chinook salmon taken in and near the Columbia River has established the following facts: (1) The fish found in the river are, with very few exceptions, mature; that is to say, they have definitely left the ocean and entered upon their spawning migration. A very few fish taken in the extreme lower end of the Columbia River estuary, and only under exceptional tidal conditions, are immature; that is, they will not mature and spawn during the year in which they are taken. (2) In contrast with this condition it has been shown that the fish taken in the ocean near the mouth of the Columbia River contain varying proportions of fish that will not mature for at least one more year. (3) These immature fish taken in the ocean belong mainly to the following age groups, arranged in the order of relative abundance: Third year, ocean nuclei; second year, ocean nuclei; third year, stream nuclei; fourth year, ocean nuclei; fourth year, stream nuclei; and fifth year, stream nuclei. (4) The percentages of mature and immature fish taken at different times during the fishing season have been determined, and it has been shown that a very high percentage (approximately 90 per cent) of the fish taken in the ocean during the early part of the season are immature. The proportion of immature fish gradually lessens as the season advances, until in August nearly 90 per cent of the fish taken are maturing. There is some indication that in September there is a return to the conditions found in May—a high percentage of immature individuals.

ABUNDANCE OF THE VARIOUS AGE GROUPS

The variations in the percentages of the various age groups taken inside the river at different times during the season are striking, especially when compared with similar data for the fish taken in the ocean. Table 9 gives for each collection of fish taken inside the percentage of fish belonging to each age group, and in the last two columns the percentage of fish with ocean and stream nuclei. The data on the percentage of fish with ocean nuclei and with stream nuclei are also shown in Figure 12. In the figure the trend, as shown by the broken line, was determined by twice smoothing the original data by threes,[6] and then further smoothing "by eye." A high percentage of fish with stream nuclei is found during the first month and a half of the season, but during the latter part of June the percentage of fish with stream nuclei decreases rapidly and fish with ocean nuclei constitute from 80 to 90 per cent of the take after the first of July. The percentages of fish with ocean nuclei are not shown in the figure, as they are merely complementary to those for the fish with stream nuclei.

Table 9.—*Composition of collections of fish taken inside the river as regards age groups*

Date	Percentage with—										Total percentage with—	
	Ocean nuclei in—					Stream nuclei in—					Ocean nuclei	Stream nuclei
	Second year	Third year	Fourth year	Fifth year	Sixth year	Second year	Third year	Fourth year	Fifth year	Sixth year		
May 10			2.4					80.5	17.1		2.4	97.6
May 13	4.3	1.4	5.0				25.9	49.7	13.0	0.7	10.7	89.3
May 16								82.5	17.5			100.0
May 17 and 18			5.6	3.7				11.1	79.6		9.3	90.7
May 27	2.3		34.1		2.3		2.3	34.1	20.4	4.5	38.7	61.3
May 30 and 31	4.8	1.2					13.3	72.3	7.2	1.2	6.0	94.0
June 10				25.0	10.0			25.0	35.0	5.0	35.0	65.0
June 16				7.1	2.0		10.2	48.0	28.6	4.1	9.1	90.1
June 16 and 17		.8	.8	15.7			8.7	52.7	20.5	.8	17.3	82.7
June 24 and 25	3.7	14.8	25.9	9.3	9.3		5.6	24.1	5.6	1.8	63.0	37.0
July 3		2.0	47.1	33.3	5.9		2.0	7.8	2.0		88.0	12.0
July 7	30.6	5.9	25.9	21.2	2.3		10.6	2.3	1.2		85.9	14.1
July 16	19.7	17.0	24.0	15.3	1.6		15.3	5.5	1.1	.5	77.6	22.4
July 28		4.0	42.0	50.0	2.0			2.0			98.0	2.0
Aug. 5	20.8		33.3	16.7	4.2	4.2	12.5	4.2	4.2		72.0	28.0
Aug. 6	10.5	6.3	46.3	29.5			3.2	3.2	1.0		92.6	7.4
Aug. 22	1.0	22.4	66.0	3.2				5.3	1.0	1.0	92.7	7.3
Sept. 12		22.1	59.0	6.3				3.2	4.2	5.3	87.3	12.7

Although it appears from these data that stream nuclei predominate during about half of the season, it must not be inferred that approximately half of the total number of fish taken during the season are of this type. The fish taken during May and June form a comparatively small part of the total pack, although an important part, owing to their fine quality. The great bulk of the run occurs during July and August. Reliable statistics are not available, but it is probable that, in most years, not more than 25 per cent of the total pack on the Columbia River is taken during May and June. On this account the percentage of the total pack formed by fish with stream nuclei will be much less than the percentage formed by fish with ocean nuclei, even though the two types are predominant for approximately equal times.

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[6] This smoothing was accomplished by smoothing independently the series of time values (10, 13, 16, 18, 27, etc.), and the series of percentage values (97.6, 89.3, 100.0, 90.7, etc.). The resulting smoothed time values were then paired with the corresponding percentage values and the pairs used as coordinates for the determination of the "smoothed" points.

Among the fish with stream nuclei, those in their fourth and fifth years are most common. A few in their sixth year are taken, but constitute a relatively small part of the total catch. Three-year-old fish are quite common, but this age group contains only precociously mature males. Two-year-old fish with stream nuclei are very rarely found.

The fish with ocean nuclei are likewise predominantly 4 and 5 years old. Fish in their sixth year are comparatively rare, but those in their third and second years are fairly common, especially during the last half of the season. It has been shown above that some of the 3-year fish with ocean nuclei are mature females, but most of the fish of this age group are males, and all of those in their second year are the precociously mature males locally known as "grilse" or "jack salmon."

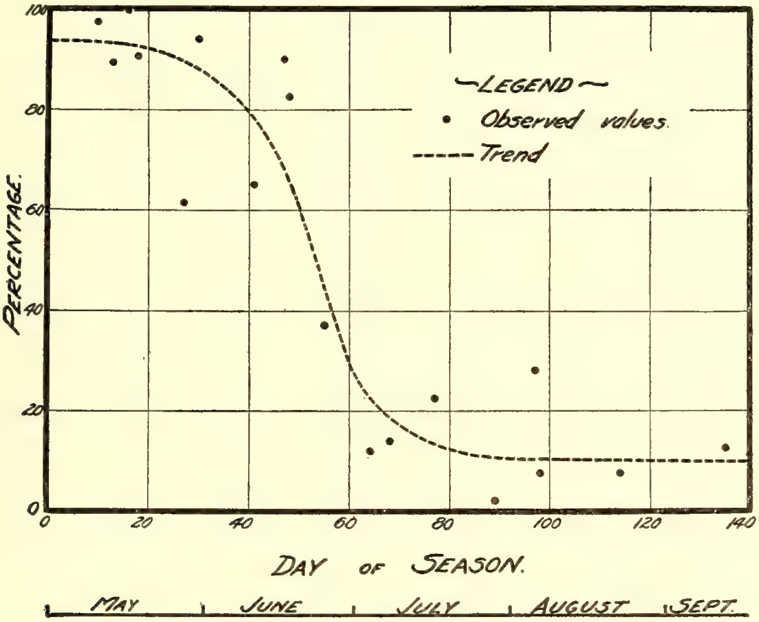

FIG. 12.—Percentage of fish with stream nuclei taken inside

The variations in the percentages of fish of the different age groups found among the fish taken in the ocean is strikingly different from those observed among the fish taken inside the river. The data are presented in Table 10 and Figure 13. The trends shown on the graph represent the position of the averages given at the bottom of the last two columns in Table 10. In view of the fact that there were no consistent changes in the percentages of fish with ocean and with stream nuclei, it appeared that the averages would represent the trends as accurately as could be done by any other means.

TABLE 10.—*Composition of collections of fish taken outside the river as regards age groups*

Date	Percentage with—										Total percentage with—	
	Ocean nuclei in—					Stream nuclei in—						
	Second year	Third year	Fourth year	Fifth year	Sixth year	Second year	Third year	Fourth year	Fifth year	Sixth year	Ocean nuclei	Stream nuclei
May 8 to 10	13.2	56.2	7.8	0.4	-------	-------	19.1	1.5	1.1	0.7	77.6	22.4
May 18	-------	42.4	26.8	13.6	-------	-------	-------	11.5	5.8	-------	82.7	17.3
May 24	23.3	43.3	20.0	-------	-------	-------	13.3	-------	-------	-------	86.7	13.3
June 4	24.2	47.5	3.3	.8	-------	0.8	18.3	3.3	1.7	-------	75.9	24.1
June 10	41.7	25.0	8.3	-------	-------	-------	25.0	-------	-------	-------	75.0	25.0
June 21	14.9	22.4	29.8	3.0	-------	-------	17.9	10.4	1.5	-------	70.2	29.8
June 25	27.3	9.1	27.3	-------	-------	-------	18.1	18.1	-------	-------	63.8	36.2
July 2	14.1	31.4	23.3	11.1	-------	-------	7.0	10.1	3.0	-------	79.9	20.1
July 28	3.0	16.4	50.0	18.5	1.0	-------	7.1	3.0	1.0	-------	88.9	11.1
Aug. 13	2.1	15.8	69.5	4.2	-------	-------	1.0	7.4	-------	-------	91.6	8.4
Aug. 13 to 17	4.9	24.5	19.6	18.6	-------	-------	1.9	2.9	26.5	1.0	67.7	32.3
Sept. 18 and 19	23.3	46.7	-------	-------	6.7	-------	10.0	10.0	3.3	-------	76.7	23.3
Average	16.00	31.80	23.80	5.85	.64	.07	11.55	6.52	3.66	.14	78.0	22.0

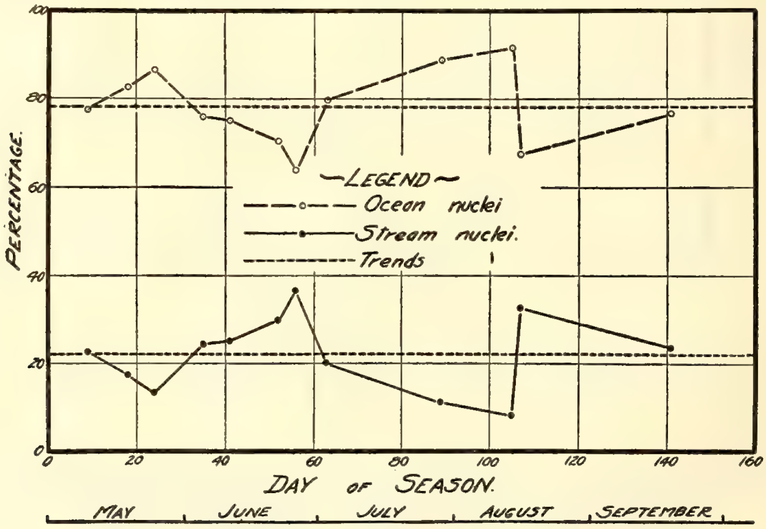

FIG. 13.—Percentages of fish with stream and ocean nuclei taken outside

One of the most notable differences between the collections of fish taken in the ocean and those of fish taken in the river is the fact just mentioned, that in the former there is no such decided and consistent change in the percentage of fish with ocean and with stream nuclei as has been described for the collections of fish taken inside. The percentage of fish with ocean nuclei taken outside varies from 63.8 to 91.6, averaging 78 per cent, and of fish with stream nuclei from 8.4 to 36.2, averaging 22 per cent. These figures are somewhat different from those given by Fraser (1920) for the chinook salmon taken during 1915 and 1916 in the Straits of Georgia, near Vancouver Island, British Columbia. Fraser found 34.6 per cent of fish with the stream type of nuclear growth and 65.4 per cent with the ocean type. In 1917, however, the same author (Fraser, 1921) found exactly the same percentage of fish with the ocean type of nucleus which we have recorded here—78 per cent.

Contrasted with this condition of relative stability in the percentages of fish with ocean and with stream nuclei, which is found among the fish taken in the ocean, are the marked variations found among the fish taken in the river and which are illustrated in Figure 12. There would seem to be but one possible explanation of these facts, namely, that the fish taken outside the mouth of the river represent a fairly accurate sample of the entire population of Columbia River chinooks contained in the ocean, and that these average percentages of fish with ocean and with stream nuclei represent, approximately, the percentage of fish with stream and with ocean nuclei that would go to make up the total of the run in the Columbia River. It is, of course, possible that races other than those belonging to the Columbia River Basin are taken off the mouth of the Columbia River, but since the Columbia is by far the most important chinook salmon stream on the coast it can hardly be doubted that the great majority of fish found just outside are native to this river. The fish found outside therefore represent the supply of fish from which the runs of mature fish found in the river are drawn. It would be expected that the removal from this supply of considerable numbers of fish with stream nuclei during the early part of the run, and of greater numbers of fish with ocean nuclei during the later part of the run, would tend to upset these ratios in a systematic manner, but this effect is not noticeable. The high percentages of immature fish taken outside would tend to obscure this effect, since the migration of mature fish would affect only the percentages of fish with ocean and with stream nuclei among the maturing fish. It seems probable, however, that with many more data than are available, some systematic fluctuations in the proportions of fish with ocean and stream nuclei might be shown.

On account of the fact that the variations in the percentages of fish with ocean and with stream nuclei among the fish taken in the ocean are practically negligible, the average percentages of fish of the different age groups taken throughout the season is significant. (This, as mentioned above, was not true of the data from the fish taken inside the river, on account of the great variations in the percentages of fish with ocean and with stream nuclei and the differences in the relative importance of the different parts of the run. See page 44.) These data are given in the bottom line of Table 10, and from them it is evident that among the fish with ocean nuclei the 3-year group is most abundantly represented, forming 31.8 per cent of the total take. The 4-year group comes next and forms 23.8 per cent of the total. Fish in their second year with ocean nuclei form the next most important group, with an average of 16 per cent. A few 5-year fish and a very few 6-year fish appear in the collections. In the case of the fish with stream nuclei it is seen that 3-year-old fish are most numerous, followed by 4, 5, 6, and 2 year fish, in the order of importance. Fraser (1920, p. 172) gives the percentages of fish of different ages of "sea type;" that is, those whose scales show the ocean type of nuclear growth, as observed in the Straits of Georgia. The figures are very similar to those obtained in this study of the fish taken off the mouth of the Columbia River, as may be seen from the following table:

TABLE 11.—*Percentages of fish with ocean nuclei in the various age groups*

Locality	Age				
	Second year	Third year	Fourth year	Fifth year	Sixth year
Off mouth of Columbia River	20.5	40.7	30.5	7.50	0.8
Straits of Georgia (from Fraser)	28.1	42.9	27.8	1.2	---------

The correspondence is remarkably close, considering the fact that the data were taken at different places, in different years, and were handled by different observers.

It is interesting to compare these data with those obtained from a study of the collections made of fish taken inside the river. Among the fish with ocean nuclei taken in the river, 4 or 5 year old fish were found to be the most numerous. Among the fish taken in the ocean, 3-year fish were most abundant. Also, in the case of the fish with stream nuclei, it was found that 4 and 5 year fish were most numerous in the river, while 3 and 4 year fish were more common in the catches made outside. It has already been pointed out that the data bearing on the proportions of fish of the different age groups present in the ocean can not be compared in detail with the similar data for the fish taken in the river, but in a general way it may be stated that the fish taken outside tend, on the whole, to be about 1 year younger than those taken inside.

GROWTH

A study has been made of the increase in length of fish of different age groups taken during the season of 1919, both outside and inside of the river. The study was confined to the collections made during a single season in order that any yearly fluctuations in growth rate might be excluded. It must be emphasized that an observed increase in the average size of the individuals contained in a series of collections is not necessarily due to growth, particularly in the case of fish taken inside the river. The constant migration upstream after fish have entered fresh water results in a constant change in the content of the run passing any given point along the river. Gilbert (1914, 1915, 1916, 1918, 1919, 1920, 1922, and 1923), in his intensive study of the sockeye salmon of British Columbia, has conclusively demonstrated the existence of distinct races characterized, among other things, by very different sizes at maturity. Considerable unpublished evidence is in the hands of the writer, which indicates that similar races are to be found among the chinook salmon of the Columbia River. The result of such differences in size of the races running in the river at various times will necessarily be to mask, more or less completely, the results of growth. The extent to which the effect of growth will be thus masked will depend upon a number of factors, such as the relative sizes and numbers of the various races found together within the river. If large races were running early in the season and smaller races later, the observed changes in size during the season would be less than the actual growth occurring within a single race. It might even occur that fish of the same age group taken late in the season would be actually smaller than others taken earlier in the season, although they had had several additional months of life in the ocean during which time they were feeding and growing rapidly. The reverse condition might also be found, in which smaller races were running early in the season and larger ones later. The effect of this would be to augment the true effect of growth.

In the case of fish taken outside, however, it seems probable that the observed changes in length quite truly represent the effect of growth, since fish of the same race presumably remain within the fishing area over the entire fishing season. That this in general is true is indicated by the fact, demonstrated above, that there is comparatively little change in the composition of the outside schools as regards age groups, and particularly the main types of nuclear growth, while at the same time very conspicuous changes are taking place in the composition of the runs in the river. The details of the growth process are necessarily lost unless they can be worked out for single races. A mixture of several races, such as we have in the collections available, will show only certain of the general features of growth that are common to at least the majority of the races represented in the collections. The results of the study of such mixed material give a composite picture, which may not exactly represent the true condition in any one of the races represented. Fraser (1920) has made an intensive study of the growth of all five species of salmon as found in the Straits of Georgia, where, as in the present study, it was impossible to segregate accurately the various races. The results of his study are interesting as showing the general trend of the growth, but it would seem that such material can not be relied upon to show the finer details of the growth process.

In order to reduce to the simplest terms the observed changes in length, the trend of these changes during the fishing season, from the 1st of May to the end of September, have been calculated. The data on fish taken in the ocean have been kept separate from those relating to fish taken in the river, and separate trends have been calculated. An examination of the data showed that the rate of change in length was, in most age groups (and by inference in others), practically constant during the season, and it was therefore assumed that the trend would be best shown as a straight line. The trends were therefore calculated on the basis of the formula $y=a+bx$, in which y is the observed length (the average of all individuals of a single age group found in any one collection), x is the day of the fishing season on which the collection was made (beginning with the opening of the fishing season on May 1), and a and b are constants. a represents the most probable average length of the age group in question on the 1st day of May, and b the most probable daily increment in length. The calculations were made by the method of least squares,[7] and the "observation equations" were weighted according to the number of individuals found in each age group in the various collections. This method of direct weighting is recommended in some of the texts on the method of least squares. The mathematical work of calculating these trends was accomplished in most cases by the use of logarithms, and the results were checked by means of a 20-inch slide rule. In the case of a few of the age groups in which the numbers involved were small, the calculations as far as the determination of the constants from the "normal equations" were done entirely on the slide rule, which gave exact figures to a sufficient number of places. The calculation of the constants from the "normal equations" was in all cases done by the use of logarithms. The following table (Table 12) gives the values of the constants *a* and *b* and the values of *y* when *x* is 100 (the most probable average length on the one-hundredth day of the season—August 8), for each age group, both for fish taken in the ocean and in the river.

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[7] See any of the numerous texts on the method of least squares.

Figures 14 to 21 show, for each age group, the average length observed in each collection and the calculated trend of the growth during the season, calculated separately for the collections made in the ocean and in the river. The upper and lower limits of twice the standard deviation is also indicated in the same manner as in the previous figures showing the variations in the size of the eggs. For the purpose of this study, both males and females have been included. The various age groups will be discussed separately.

TABLE 12.—*Data for the trends in length of chinook salmon taken during 1919*

Age group	Number of specimens	*a*	*b*	Value of *y* when *x* equals 100
FISH TAKEN IN THE OCEAN				
Ocean nuclei				
Second year	121	42.97	0.0888	51.85
Third year	322	60.20	.1193	72.14
Fourth year	194	77.65	.1410	91.75
Fifth year	37	92.02	.0610	98.12
Stream nuclei				
Third year	117	48.57	.0979	58.36
Fourth year	40	72.10	.1169	83.79
Fifth year	11	83.50	.1064	94.14
FISH TAKEN IN THE RIVER				
Ocean nuclei				
Second year	90	44.54	−.0252	42.02
Third year	99	48.98	.1989	68.87
Fourth year	319	79.10	.0771	86.81
Fifth year	166	111.10	−.1051	[1] 100.59
Sixth year	19	104.70	.1546	120.16
Stream nuclei				
Third year	115	47.30	.0956	56.86
Fourth year	489	75.00	.0671	81.71
Fifth year	147	92.30	.0832	104.98
Sixth year	17	112.05	−.0600	106.05

[1] The fish of this age group taken on June 16 and June 16 and 17, 1919, were unusually large. Both collections were taken well up the river, one at Seufert and the other at Warrendale, and it is difficult to escape the conclusion that these fish are representative of a large race. Omitting these two collections the constants become: $a=100.5$, $b=0.0015$, and the value of *y* when *x* is 100 is 100.65.

FISH IN THEIR SECOND YEAR, OCEAN NUCLEI

Figure 14 shows the variations in the length of fish of this age group. The differences between the fish taken outside and those taken inside are conspicuous. The trend of those taken outside is upward, from nearly 43 cm. on the 1st of May to nearly 52 cm. on August 8, 100 days after the opening of the season. The change in length during the first 100 days of the season has been used simply as a matter of convenience in calculation and discussion. In the text figures the trend is extended beyond this point. The points that show the average size of the fish of this age group taken in the various collections are distributed quite closely about the trend. The fish that were taken in the river, however, tend to be smaller toward the end of the season than at the beginning, as is shown by the downward slope of the line of trend, and the deviation of the points from the trend is distinctly greater than in the case of the fish taken outside.

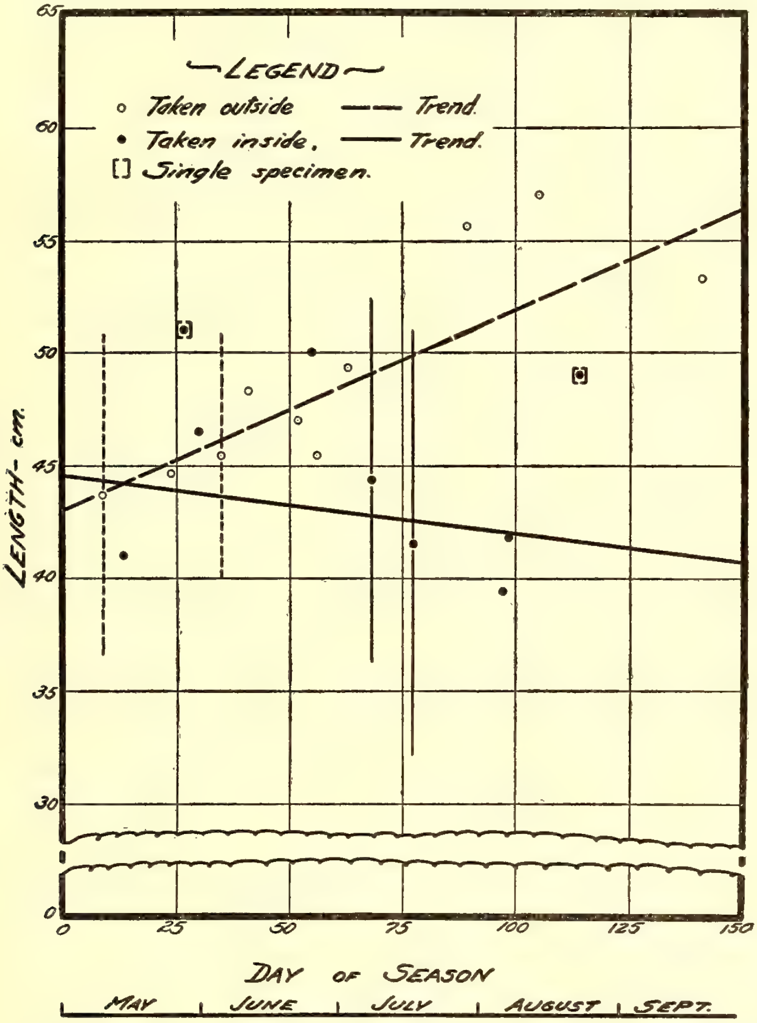

FIG. 14.—Length of fish in their second year, ocean nuclei. As in the illustrations showing sizes of eggs, the upper and lower limits of twice the standard deviation (± 2σ) are shown by the vertical lines extending from the points that indicate the position of the mean. The same conventions have been used in the other illustrations of length

FISH IN THEIR THIRD YEAR, OCEAN NUCLEI

Figure 15 shows the variations in the length of the fish in their third year, ocean nuclei. The trends for the fish of the two groups—those taken outside and those taken inside—differ materially, although in quite another manner than was noted in the fish with ocean nuclei in their second year. In the 3-year-old fish, the trend for the individuals taken inside is much steeper than that for those taken outside, indicating a more rapid increase in size during the season. The trend for the fish taken outside starts at about 60 cm. on the 1st of May and is increased to a little over 72 cm. by the 8th of August. As in the case of the 2-year-old fish, the variation about the trend of the points indicating the average size found in the various collections is less in the case of the fish taken in the ocean than among the fish taken in the river.

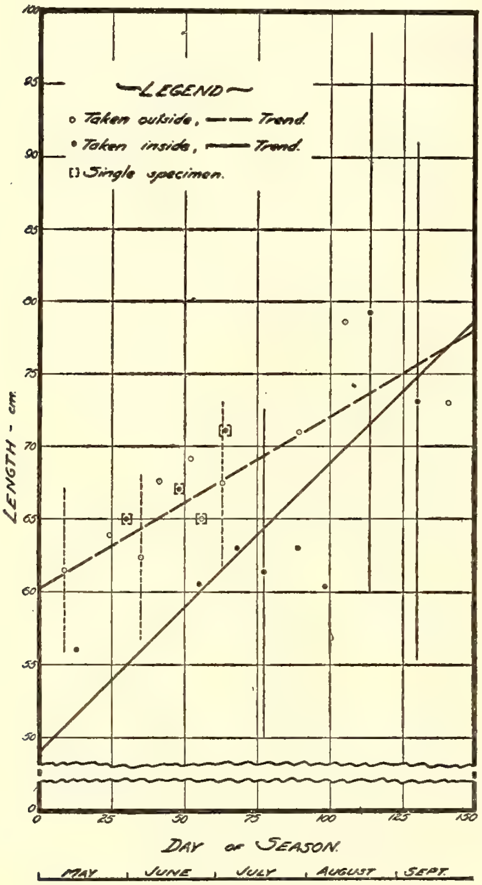

FIG. 15.—Length of fish in third year, ocean nuclei

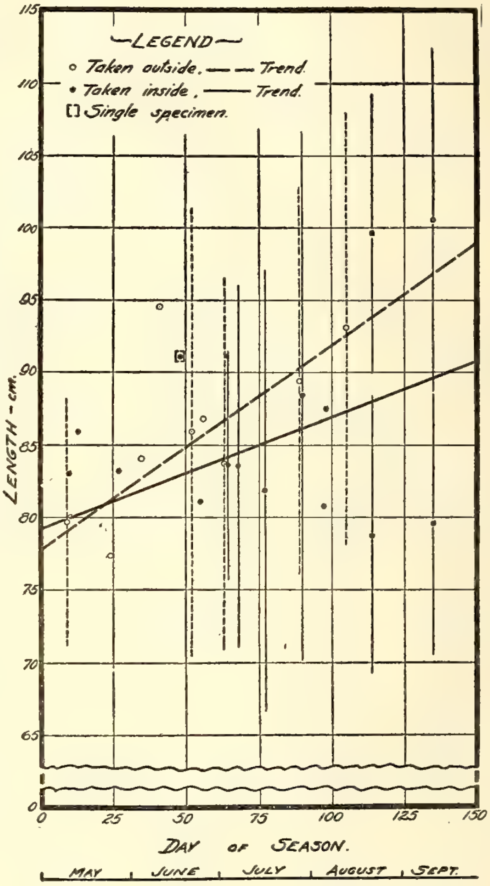

FIG. 16.—Length of fish in fourth year, ocean nuclei

FISH IN THEIR FOURTH YEAR, OCEAN NUCLEI

The data and the trends for the fish of this age group are shown in Figure 16. The trend for the fish taken outside starts at 77.7 cm. and increases to 91.7 cm. by the 8th of August. The corresponding trend for the fish taken inside is much less steep, starting at 79.1 cm. and reaching a value of only 86.8 by the same date. As in the two age groups previously discussed, the deviation of the points from the trends is greater in the case of the fish taken inside.

The study of the fish of this age group taken in the river is complicated by the fact that two quite distinct races are found running simultaneously during the latter part of August and September. A discussion of the racial differences observed among the chinook salmon has not been attempted in this paper, but in this particular case the differences are so striking that a failure to segregate the two races would be misleading. Tables 19 and 20 on pages 82 and 83 give the length-frequency distributions in detail for two large collections made, respectively, on August 22 and September 12, 1919. An examination of these tables will show that the length-frequency distributions of the 4-year fish with ocean nuclei are distinctly bimodal. The bimodality is apparent, not only in both collections but also in the two sexes of each collection, as well as in the distribution in which males and females are combined. The cumulative evidence of these facts points strongly to the fact that two distinct races are present. Additional evidence of a very satisfactory nature, which supports this interpretation, is available from the scales. Two quite different types of scales are found among the fish of this age group: One, typical of the smaller fish, is characterized by a comparatively small ocean nucleus, which is usually not sharply defined from the succeeding growth of the second year, and the winter bands of the second and third years are relatively close together. The type that is associated with the larger fish has a distinctly larger nucleus, which is usually well set off from the rest of the scale. The second and third winter bands are more widely separated and are frequently less sharply marked than those of the other type. Figure 41 illustrates the scales of the first type—associated with the smaller sized fish—and Figure 42 illustrates the scales of the second type. The evidence given by the length-frequency distributions and by a careful study of the scales indicated that there was very little overlapping in the sizes of these two races, and consequently the line of separation has, somewhat arbitrarily, been set at 90 cm. All of the fish above this size have been considered as belonging to the larger race, and all below it as belonging to the smaller race. The overlapping of the two races is quite obviously so slight that there will be little error in making this assumption. In the text figure the two races have been shown separately in the last two collections. Both races were included in the calculation of the trend.

FISH IN THEIR FIFTH YEAR, OCEAN NUCLEI

It has been shown above that there were comparatively few fish of this age group taken outside the river, although it is well represented among the fish taken inside. It is significant, therefore, that the trend, as determined from these relatively inadequate data from outside, is quite similar to the trends as determined for the other age groups found among the fish taken outside, which were much more adequately represented. On the other hand, the trend for the fish taken inside is reversed, the larger fish occurring during the early part of the season, although the group is well represented both as regards number of individuals and number of collections. The deviations from the line of the trend are again greater in the case of the fish taken inside the river. These features are shown in Figure 17.

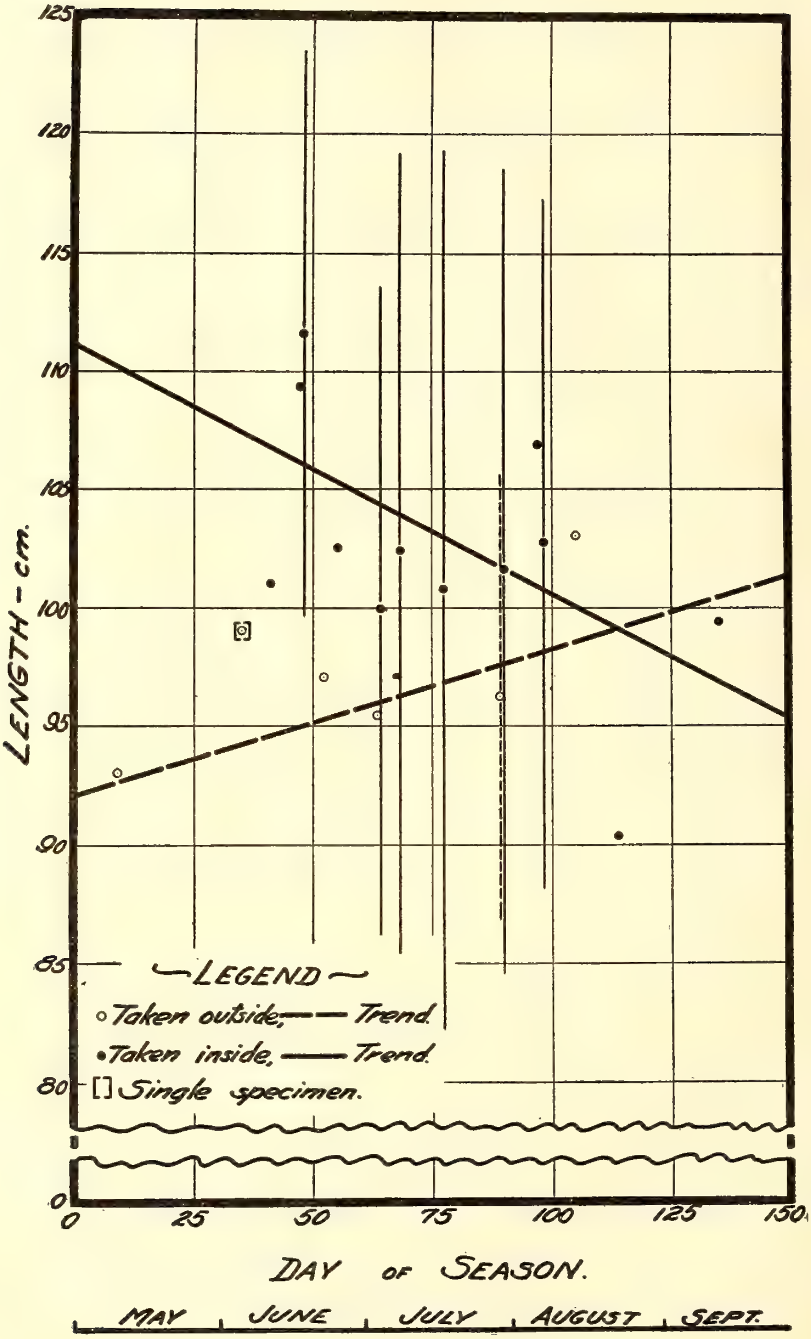

FIG. 17.—Length of fish in their fifth year, ocean nuclei

FISH IN THEIR SIXTH YEAR, OCEAN NUCLEI

This age group is so poorly represented among the fish taken outside that it is impossible to learn anything of the general trend of the growth. The group is by no means adequately represented among the fish taken inside, but for the sake of completeness the trend has been calculated and is shown in Figure 18. It can not, however, be considered as reliable.

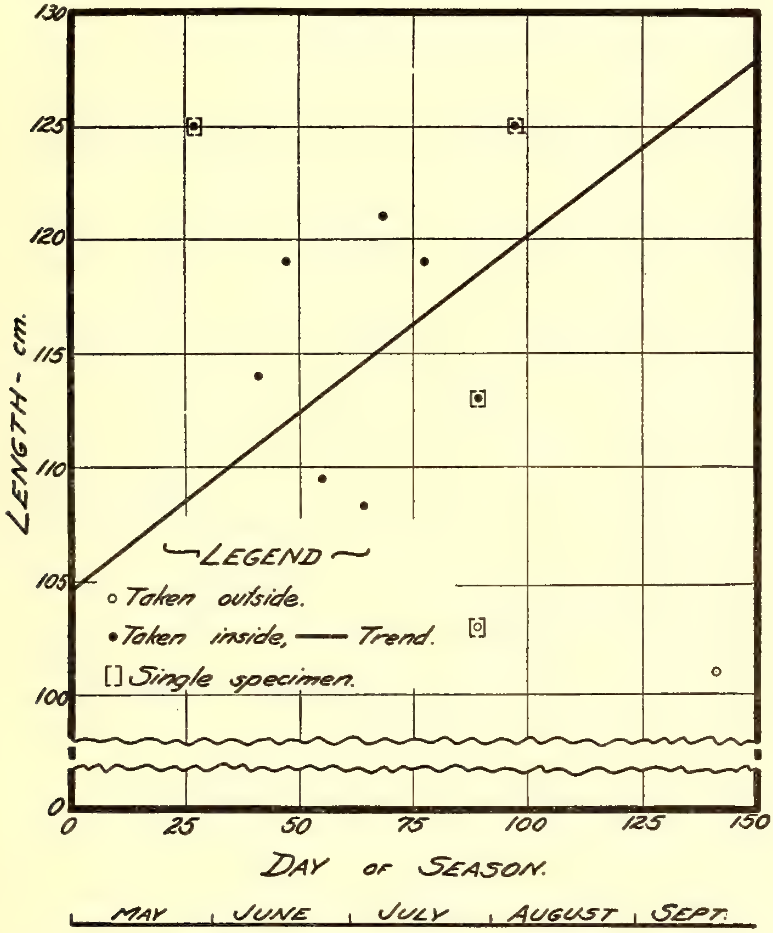

FIG. 18.—Length of fish in their sixth year, ocean nuclei

FISH IN THEIR THIRD YEAR, STREAM NUCLEI

The data for this age group are shown in Figure 19. The trends for the fish taken inside and those taken outside run close together and almost parallel—the only example among all of the age groups in which this is the case, although it might well be expected that this would happen in the majority of instances, were it not for the influence of factors other than growth, such as the presence of a succession of various races. As shown by these trends, the fish of this age group averaged about 48 cm. in length at the beginning of the season in 1919, and increased approximately 10 cm. between that time and August 8. The greater variability of the fish taken inside is not as clearly shown in this group of fish as in many of the others, but a consideration of the actual deviations of the observed average lengths from the calculated lengths (the residuals) shows that even in this instance the fish taken inside are distinctly more variable. The average deviation from the trend among the collections taken inside is 1.8 cm., and among the fish taken outside is only 0.9 cm.

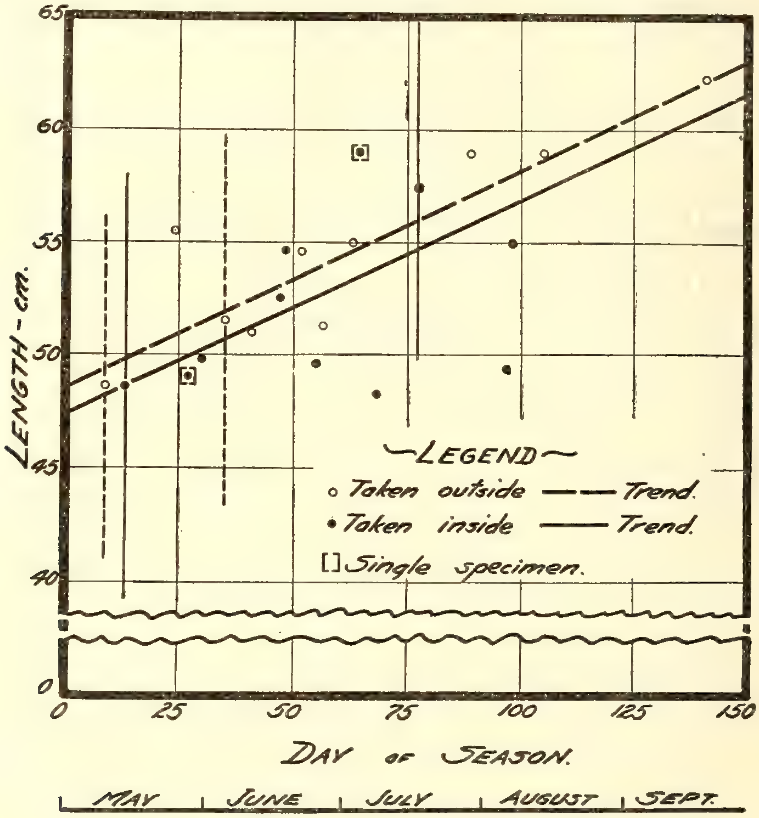

FIG. 19.—Length of fish in their third year, stream nuclei

FISH IN THEIR FOURTH YEAR, STREAM NUCLEI

Figure 20 shows the data for the fish of this age group. As in the last group considered, the trends of the fish taken inside and outside are in fair agreement, although the agreement is by no means as close as in the 3-year fish. Only 40 individuals, scattered through 8 collections, represent this age group among the fish taken outside, while there were 489 individuals in 16 collections taken inside. Yet the average deviation of the points from the trends is distinctly less in the case of the fish taken outside.

FISH IN THEIR FIFTH YEAR, STREAM NUCLEI

Only 11 fish of this age group appear in the collections of fish taken in the ocean during 1919. These were scattered through six collections and yet give a trend similar to the other trends shown by the fish taken outside. The trend for the fish taken inside is quite similar, but runs considerably higher. The data are shown in Figure 21, and an inspection of this graph shows again the greater variability of the average sizes of the fish taken inside.

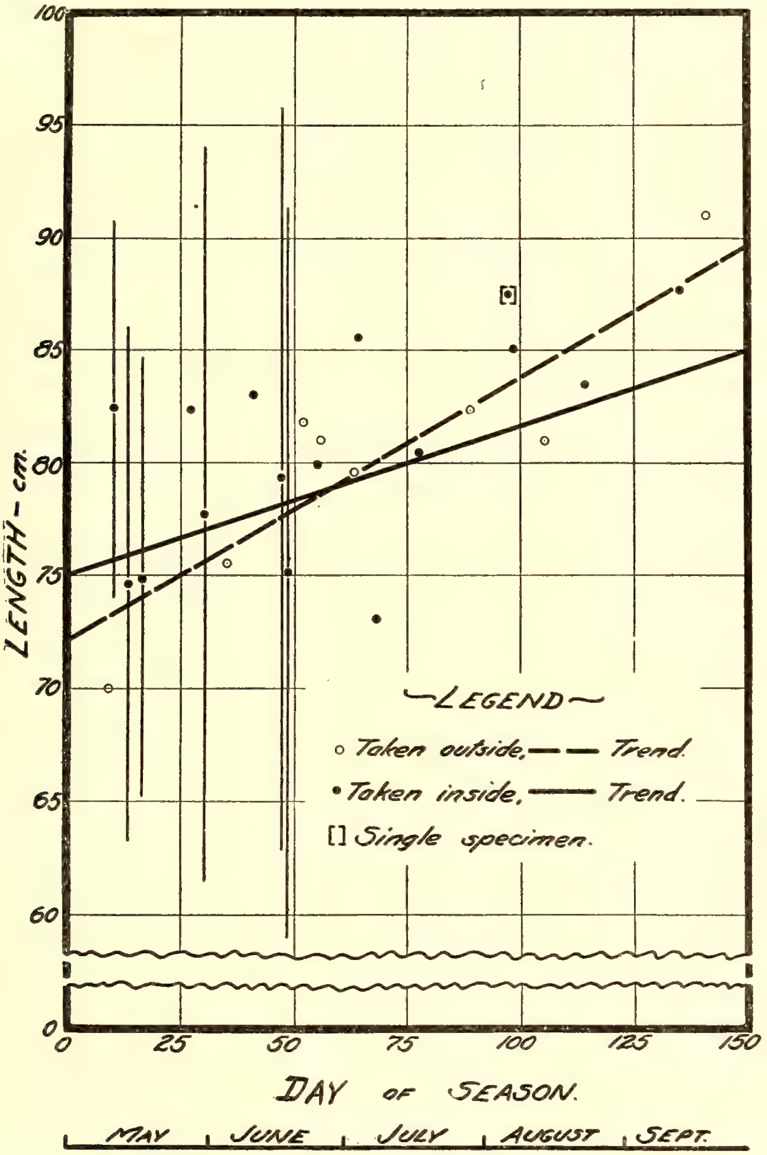

FIG. 20.—Length of fish in their fourth year, stream nuclei

FISH IN THEIR SIXTH YEAR, STREAM NUCLEI

No fish of this age group were taken outside of the river, and only 17 inside. A text figure, therefore, has not been prepared to show these data, although the values of the constants determining the trend have been given in Table 12. That the trend would be reversed is indicated by the negative value for *b* as given in the table. Although, with so few individuals, such a trend can not be considered very reliable, it is worthy of some consideration in view of the fact that, among the fish taken inside the river, there were two other age groups, both of which were well represented but which showed a similar negative trend.

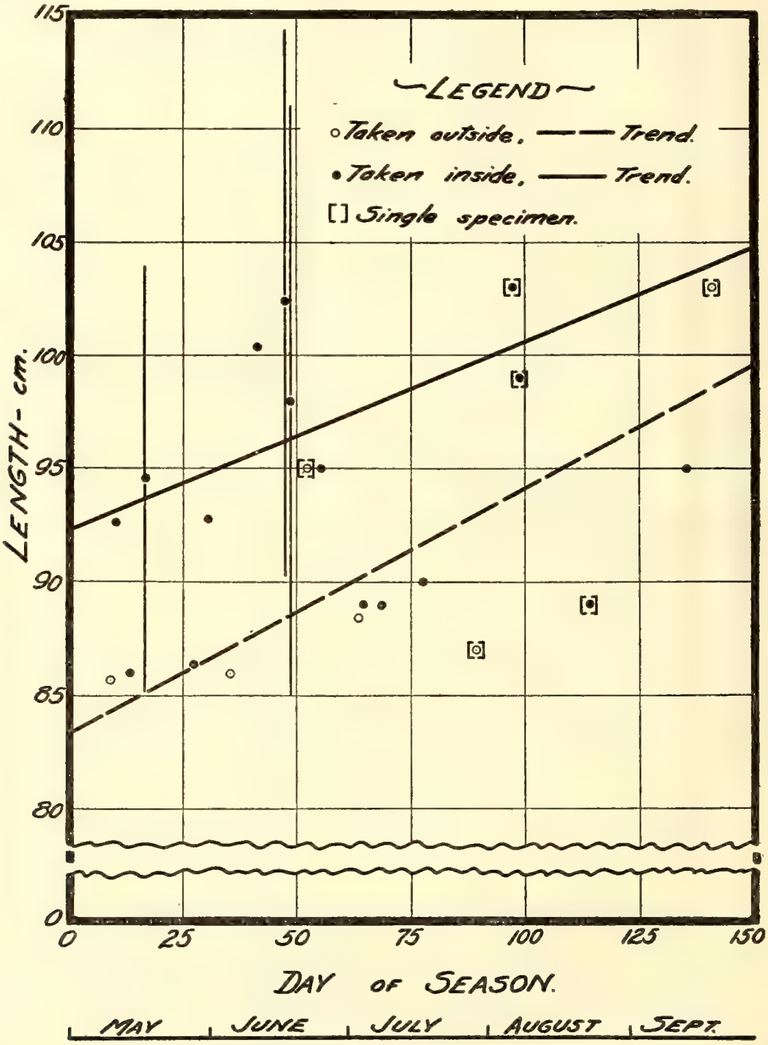

FIG. 21.—Length of fish in their fifth year, stream nuclei

Several important facts are shown by these data on the length of the fish.

An examination of the tables and text figures given above shows clearly that in all of the age groups represented among the fish taken in the ocean a marked increase in length occurs during the fishing season, from May to September, inclusive. Similar increases in length are shown in five of the age groups taken inside the river, but in three of the age groups—the 2-year and the 5-year fish with ocean nuclei and the 6-year fish with stream nuclei—the trend is reversed and the fish belonging to these age groups are smaller toward the end of the season than earlier. It is also noticeable that, even excluding these age groups in which the trend is reversed, the trends for the fish taken inside are more variable than for the fish taken outside. The average daily increment (*b* in Table 12) for the fish taken outside varies from 0.0888 to 0.1410 cm., while that for the groups taken inside, omitting those age groups in which the trend is downward, is much greater, ranging from 0.0671 to 0.1989. This is over two and one-half times that shown by the fish taken outside. Attention has also been called repeatedly to the fact that in each age group the deviations of the average lengths for each collection (shown as the points in the figures) from the trend (as determined from the series of collections taken over the whole season) is greater among the fish taken in the river than among those taken in the ocean. All of the evidence available indicates a decidedly greater variability among the fish taken inside. A few instances of this sort might be attributed to chance, but the uniformity of the evidence demands some other explanation.

It seems very probable, if not, indeed, certain, that this greater variability in the rate of increase in length among the fish taken in the river is due to the fact (which has been mentioned above) that there are more profound changes in the racial constitution of the fish found migrating up the river than in those found schooled outside, and that these different races vary sufficiently in their average size so that the effect of growth may be masked more or less completely by these racial changes. Evidence has been presented which shows that both of these factors are present in the migrating fish within the river. It seems hardly necessary to argue that there is a succession of races during the season among the migrating fish. Granting the existence of such races it follows that there must be a succession of them in the river during the season, so that at one time the run contains a conspicuously large percentage of fish from one or at most a few races, while at other times other races will predominate. This would be particularly true in the case of such a large river system as the Columbia with its numerous tributaries, which probably have, as Gilbert has shown for the sockeye salmon, each its individual race. It has been shown in one specific instance—that of the 4-year fish with ocean nuclei taken during August and September, 1919—that distinct races are to be found among the chinook salmon of the Columbia River, and, moreover, that these races may vary sufficiently in size so that the predominance of one of them at one time and another at another time would undoubtedly greatly modify the true effect of growth.

The reversed, downward trend of the fish belonging to some of the age groups—the fish in their second and fifth years with ocean nuclei and those in their sixth year with stream nuclei—may be explained, then, by supposing that the races that predominate in these age groups early in the season are large and those running late are small. Such characters might, however, fluctuate from year to year, so that samples collected in other seasons might not show exactly the same effect. It is not necessarily to be expected that the trends of the fish of different age groups taken inside will run parallel with each other, even though they do not run parallel with the trends for the fish taken outside. It may well happen that at any given time one race of fish will predominate among the fish of one age group, and that an entirely different race will be predominant in another age group. The evidence is not available to prove this for the Columbia River chinook salmon, but Gilbert has shown, in his extensive studies of the sockeye salmon, that different races may show quite different distributions among the different age groups. It may be inferred that similar conditions would be found among the chinook salmon if sufficient evidence were available. The possible effect of such a succession of different races should be carefully considered in any detailed study of growth in which this factor may have an opportunity to operate.

It has been shown that there are probably no radical changes in the racial constitution of the fish found in the ocean outside the mouth of the river. It has also been shown that the fish taken in the ocean are, in varying measure, immature, and that many of them are not destined to enter the river during the year in which they are taken. In consideration of these facts, it seems reasonable to suppose that the increase in size of the fish taken in the ocean reflects, with reasonable accuracy, the true effect of growth. If this be true, it is evident that most of the growth of the year takes place during the fishing season—that is, during the late spring and summer. This is shown by the fact that the fish of any one of the age groups are, at the end of the season, nearly equal in size to the fish of the next older age group at the beginning of the season. This is quite to be expected since it has been shown by numerous studies on various fish and other marine and fresh-water organisms that the main growth occurs during this part of the year. Fraser (1917) has shown that the chinook salmon found in the Straits of Georgia make their most rapid growth during this season—80 per cent of the total growth of the year taking place during the months from April to September, inclusive. These figures must, however, be considered as very general, since in computing them Fraser made use of the yearly increment of growth in fish of all age groups. In his investigation of the growth of the Pismo clam, Weymouth (1923) found that the period of most rapid growth usually came during May to September, inclusive. The writer (Rich, 1920) has shown that the period of most active growth in young chinook salmon previous to or during their seaward migration occurs during the spring and summer but varies somewhat with the locality. In the Columbia River, the most rapid growth occurs between May and September, inclusive, and in the Sacramento River from March to July, inclusive. Weymouth points out that the rate of growth is profoundly affected by variations in temperature, being induced and accelerated by higher temperatures. The earlier occurrence of the period of most rapid growth in the young salmon of the Sacramento River, when compared with those in the Columbia River, is undoubtedly due to the earlier warming of the Sacramento water. Numerous other examples, showing that the most rapid growth occurs during the spring and summer, might be cited, and it seems certain that for most organisms the more rapid growth occurs during the warmer part of the year.

Since the data on which this paper is based were taken entirely during the months from May to September, inclusive, the trends that have been calculated for the fish taken in the ocean represent the average slope of the growth curve during the period of most rapid growth. In order to show the general appearance of the total growth curve for chinook salmon, these trends have been used in preparing Figures 22 and 23, showing growth curves for fish with the ocean type of nucleus and with the stream type of nucleus, respectively. Such a use of these data is not strictly justified, as the data were all taken during a single year (1919), so that the individuals belonging to each separate age group came from different broods. The fish in their second year came from eggs deposited in 1917, those in their third year from the brood of 1916, and so on. The most logical method for preparing such a growth curve would be to have data over a series of years so that the growth of the fish derived from a single brood year could be obtained. Lacking this, it has seemed desirable to present in this form such data as are available.

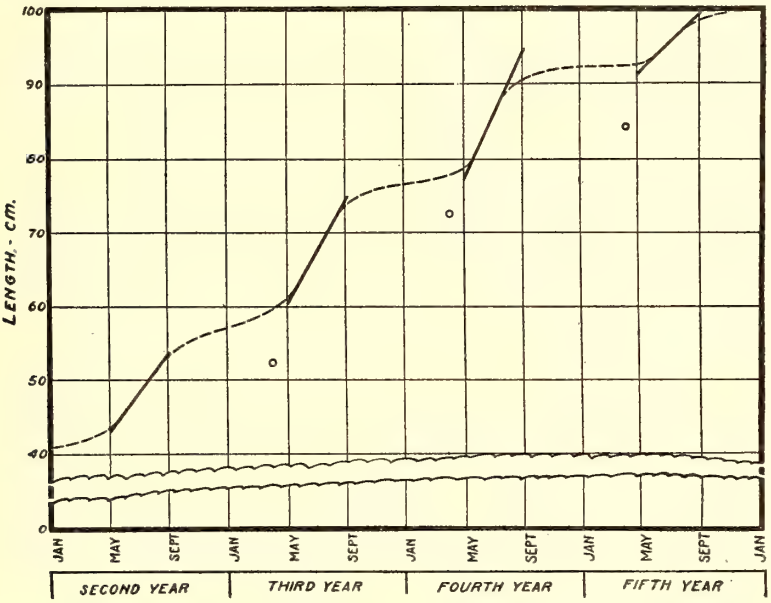

FIG. 22.—Growth curve of chinook salmon that migrated seaward as fry (scales with ocean type of nuclei). Data from fish taken in the ocean near the mouth of the Columbia River. Solid lines show the trends of growth during the fishing season; broken lines indicate roughly the probable course of growth during the remainder of the year; circles show the size of chinook salmon taken in the Straits of Georgia, as given by Fraser. Fraser's measurements did not include the caudal rays, while our's did

In the illustrations the calculated trends are shown by the solid lines, and the trends for successive years have been connected by dotted lines. No data are available upon which to base the form of these connecting lines. They have therefore been drawn in "by eye." The resulting growth curve probably represents fairly well the average size of these fish at different ages and at different seasons. Some error is doubtless due to the use of a straight-line trend as showing the size during the period of rapid growth. The growth during the first and the last parts of each growth period is probably slower than indicated, while that at the height of the growing season is somewhat more rapid. The data available, however, do not lend themselves to a more detailed analysis.

The general form of the growth curve thus obtained is typical and consists of a series of steps, rising rapidly during the summer season and more gradually during the rest of the year. Similar growth curves have been presented by a number of authors and have been obtained by the writer in an unpublished study of young steelhead trout. For the sake of comparison, the data given by Fraser (1917) for the size of chinook salmon taken in the Straits of Georgia have been indicated on the figures. Fraser gives the size of fish of the different age groups at the end of each year as calculated from scale measurements. Since he has considered April 1 as marking the beginning of the new growth period, his data for the length of fish at the end of each year have been placed on the ordinate corresponding to this date. His data are not exactly comparable with ours, since his measurements do not include the caudal rays, while ours do so. On this account his figures fall consistently below those for the Columbia River fish but near enough so that it seems probable that the differences are due almost entirely to the different measurements used. There is very little variation in these differences, Fraser's figures being 6 to 10 cm. lower than ours.

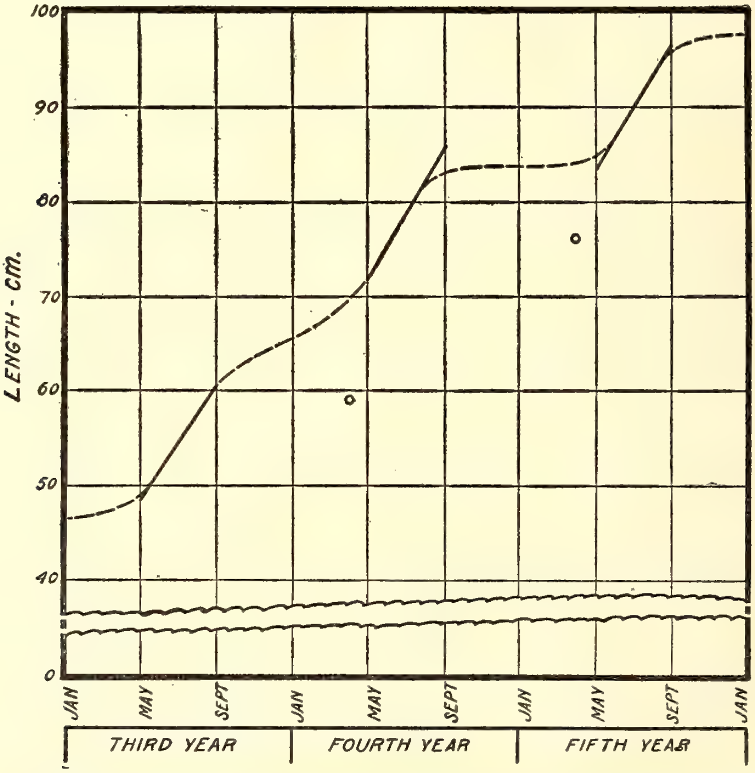

FIG. 23.—Growth curve of chinook salmon that migrated seaward after spending one year in fresh water (scales with stream type of nuclei). For explanation see Figure 22

The agreement in the data from the Straits of Georgia and from the ocean near the mouth of the Columbia River is remarkably close, considering the different conditions under which the data were collected. The growth is apparently nearly identical in the two localities. It seems evident that the growth curves given in Figures 22 and 23 represent quite accurately the average size of chinook salmon during their life in the ocean.

The results of this study of growth may be summarized as follows:

1. Examination of the trends of the variations in size of the different age groups during the season has shown that the variations are much more irregular among the fish taken in the river than among those taken in the ocean. Evidence is presented to show that these irregularities are due to variations in the racial constitution of the fish taken in the river. On this account the data from this source are not suitable as a basis for a study of growth. The data obtained from fish taken in the ocean is, however, suitable for such a study.

2. A growth curve has been based on the trends obtained from the study of the fish taken in the ocean. It has the form typical of organisms the growth of which continues over a series of years and shows seasonal fluctuations in rate. The agreement with similar data obtained by Fraser in his investigation of the salmon of the Straits of Georgia is very close—a fact which indicates that the growth curve presented in this paper may be relied upon to show the average size of chinook salmon in the general region of the Columbia River and Puget Sound during the greater part of their life in the ocean.

FISH TAKEN IN MONTEREY BAY

A few data are available from the chinook salmon taken by troll in Monterey Bay, Calif. A collection of scales was made during the summer of 1915, and at the same time a collection of egg samples was made. The egg samples were merely taken from the cleaning tables and, since the value of the size of the eggs in determining the relative maturity had not then been established, no attempt was made to take data and scales from the fish from which the eggs came. In fact, this value first became apparent through the study of this collection. In the summer of 1918 (June 19 to 21), a small collection of females was made and egg samples taken and tagged so that they could be identified with the corresponding scales and data. At the time this collection was made it was the intention to obtain many more data, but the fishing happened to be unusually poor and only 63 females could be obtained in the time available. The study of these few data has proved interesting, although they form an inadequate basis for final conclusions. More extensive studies of the fish taken in Monterey Bay are being made by the California Fish and Game Commission under the direction of Prof. J. O. Snyder, assisted by E. A. McGregor, to whom the writer is indebted for the privilege of examining some of their unpublished data.

SIZE

The length-frequency distributions for the various age groups found in the collections made in 1915 and 1918 are given in Tables 22 and 24 on pages 84 and 86. The number of individuals belonging to each age group and the average lengths are given in Table 13.

Table 13.—*Number of specimens and average length of salmon of each age group taken at Monterey*

	June 16, 1915		June 19 to 21, 1918			June 16, 1915		June 19 to 21, 1918	
	Number	Average length, centimeters	Number	Average length, centimeters		Number	Average length, centimeters	Number	Average length, centimeters
Ocean nuclei:					Stream nuclei:				
Second year	30	53.27	2	47.00	Third year	1	59.00	1	57.00
Third year	28	76.07	51	72.64	Fourth year	6	81.33	3	80.30
Fourth year	25	87.72	6	91.30	Fifth year	2	93.00	-------	---------
Fifth year	14	96.60	-------	---------					

A comparison shows that these figures are, in the main, in fair agreement with the data from the Columbia River. A slight tendency is apparent, especially among the fish of the younger age groups, for the fish taken at Monterey to run larger than did the Columbia River fish in 1919, but many more data than are at present available will be necessary before this can be asserted with any certainty.

PERCENTAGES OF THE VARIOUS AGE GROUPS

The collection made in 1915 can not be considered as showing the proper percentages of fish of the various age groups. It was taken at a time when the fish were so segregated at the cannery that a random sampling was impossible. Individuals were sorted into three lots, according to size. One contained fish less than 5 pounds in weight, which was, at the time, the legal limit below which the fish could not be sold. Many fish of this size were taken by the fishermen and were brought to the canneries, only to be discarded. The second group contained fish between 5 and 15 pounds in weight, and the third group those above 15 pounds. In collecting these data it was necessary to handle the various sizes separately, and it was, therefore, impossible to get a fair sample of the take as a whole. The collection made in 1918 contains practically all of the females that were brought to one of the large canneries and to several of the smaller fish dealers during the period of three days in which the collection was made. It therefore represents a fair random sample of the take at that time. The percentages of fish of the different age groups are given in Table 14. The table also gives the percentages of fish of the different age groups as found by Mr. McGregor of the California Fish and Game Commission. His collection contained over 200 specimens taken between June 4 and June 22, 1921.

Table 14.—*Percentages of fish of different age groups in Monterey Bay*

Date	Age group							
	Ocean nuclei					Stream nuclei		
	Second year	Third year	Fourth year	Fifth year	Sixth year	Third year	Fourth year	Fifth year
June 19 to 21, 1918	3.2	81.0	9.5	----------	----------	1.6	4.7	----------
June 4 to 22, 1921	1.9	70.8	13.6	6.6	0.5	1.9	3.3	1.4

There is a remarkably close agreement between the figures for these two collections, when it is considered that they represent different years and the work of two entirely independent observers. The proportion of fish with ocean and with stream nuclei is almost identical—6.3 per cent of the 1918 collection and 6.7 of the 1921 collection having scales with the stream type of nuclei.

It was shown above that the percentage of fish with stream nuclei among the schools off the mouth of the Columbia River was close to 22 per cent, and the fact was mentioned that Fraser has found that 34.6 per cent of the chinook salmon taken during 1915 and 1916 in the straits of Georgia showed the stream type of nucleus. Although in 1917 Fraser found that the percentage of fish with the ocean type of nuclear growth was 78 per cent, identical with our findings in the fish taken near the mouth of the Columbia, it would seem probable that the salmon in the Straits of Georgia tend to contain a larger percentage of individuals that have remained an entire year in fresh water before migrating seaward. Gilbert (1922a) has found that the chinook or king salmon of the Yukon River invariably have scales with the stream type of nucleus.

These data indicate with considerable certainty that latitude, or more properly the differences in climatic conditions obtaining in different latitudes, has a definite effect upon the early history of the chinook salmon. In the more southerly latitudes the tendency is for the young fish to migrate soon after they become free-swimming, early in their first year. Under the influence of the more severe climatic conditions of the north, which cause later hatching and slower growth, the tendency is for greater and greater percentages of the fish to remain in the home stream during the first year.

A similar condition has been found to exist among the salmon of Norway. Dahl (1910) gives tables showing for three localities and for two years the percentages of these salmon that migrate seaward after spending 2, 3, 4, and 5 winters in fresh water. He concludes:

> A close examination of these tables shows that the age of the smolts at migration varies between 2 and 5 winters. In the south the smolts are generally young, but the farther north we go the more pronounced is the tendency for the fish to remain longer in the river before migration.

In this connection it is interesting to note that in a large river basin such as that of the Columbia River a distribution of races is found which is suggestive of this distribution in latitude. It is certain, from unpublished data in the hands of the writer, that as a rule the races in the Columbia which spawn in the higher tributaries are predominantly those which have the habit of remaining in fresh water during the first year and whose scales, therefore, show the stream type of nucleus. The races in the lower tributaries, on the other hand, migrate, as a rule, during the first year, and as a result the scales of the adults show the ocean type of nuclear growth. It is evident, therefore, that the effect of altitude on the early history of the chinook salmon is very similar to the effect of latitude—an increase in either altitude or latitude resulting in an increase in the number of young that remain in the stream during the entire first year. This similar influence of altitude and latitude is well known from the numerous studies of the geographical distribution of land animals and plants, and it is interesting to note the parallel effect on racial habit in such an anadromous form as the chinook salmon.

RELATIVE MATURITY

In the matter of relative maturity the salmon of Monterey Bay do not differ greatly from those taken off the mouth of the Columbia River. The distribution of egg sizes, as found in the collection of eggs made in 1915, is given in Table 23. In this table the egg sizes are given separately for the three size groups mentioned above—that is, for the fish less than 5 pounds in weight (Group 1), for those between 5 and 15 pounds (Group 2), and for those over 15 pounds (Group 3). Group 2 is composed largely of fish in their third year with ocean nuclei, and the distribution of egg sizes in this age group has been shown separately in Figure 3. Table 25 gives the distribution of egg sizes as found in the 1918 collection. Figure 24 shows the distribution of egg sizes for both the 1915 and the 1918 collections. The general appearance of the two distributions is quite similar, although many more mature fish were taken in 1915 than in 1918, probably due to the selection involved in making the first collection, which has been mentioned above. A distinct bimodality is apparent in both collections. One mode appears in both at log *D* 0.17 and another at log *D* 0.39. The two modes in the distribution of egg sizes in the fish in their third year with ocean nuclei, as shown in Figure 3, are at the same points. Of the two groups shown in Figure 24 the fish with the larger eggs would undoubtedly have matured during the year in which they were taken, while the others would not have matured for at least one more year. There is obviously a certain amount of overlapping, which is especially evident in the 1915 collection. An examination of Table 23 on page 86 shows that the overlapping is entirely within the group of fish weighing from 5 to 15 pounds. The distribution of egg sizes within this group

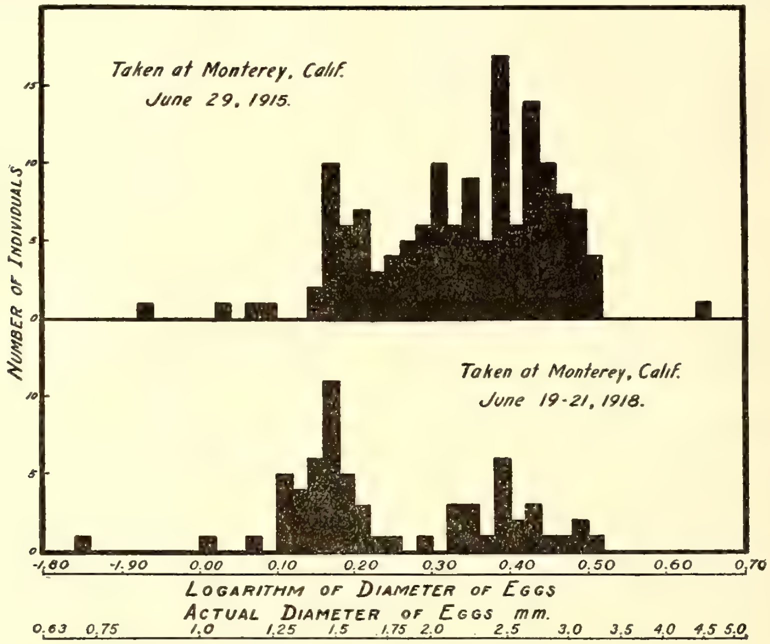

FIG. 24.—Distribution of egg sizes as found in two collections made at Monterey, Calif.

is quite irregular but is obviously bimodal. It has been possible, by the application of statistical methods, to separate the two component curves with some degree of satisfaction, but in view of the fact that the material is selected and therefore not representative it seems unnecessary to discuss this in detail. It is apparent from the table that all of the fish contained in the group weighing less than 5 pounds were immature and that all above 15 pounds in weight were destined to mature during the year in which they were taken.

The percentage of mature and immature fish can not be determined from the data available for 1915 on account of the selection involved in making the collection. The 1918 collection, although inadequate, gives some indication of the relative number of mature and immature fish present in Monterey Bay at the time the collection was made. In Table 25 (p. 87) and Figure 24 it is shown that the lines separating the two distinctive egg sizes comes at approximately log *D* 0.30. With the exception of one individual, for which the log *D* is 0.29, the two groups are well separated. If we include this doubtful individual with the group having the larger eggs, this group will include 24 individuals and the group with smaller eggs will contain 39 individuals. On a percentage basis, then, this collection contains 38.1 per cent mature and 61.9 per cent immature individuals. This agrees very closely with the data from the Columbia River. In Figure 11 the trend of the percentage of mature fish taken in the ocean near the mouth of the Columbia River shows that on the fiftieth day of the season, June 19, the catch contained 40 per cent of mature fish. Such a close agreement as this is doubtless accidental, but it indicates strongly that the relative maturity of the chinook salmon in Monterey Bay is, during the latter part of June at least, approximately the same as that of the salmon found in the ocean near the mouth of the Columbia River.

FISH FROM DRAKES BAY AND FORT BRAGG

A small collection of scales and eggs was made on August 15 and 16, 1918, by representatives of the California Fish and Game Commission from fish taken by troll in the region of Drakes Bay. This bay is located about 30 miles north of the Golden Gate and is one of the centers from which trolling is conducted. Scales and eggs from 12 chinook salmon taken near Fort Bragg were also taken on July 17. Since both collections were small, and separate study has disclosed no marked differences, they have been combined in the tables presented. Unfortunately serial numbers were not given to both scale and egg samples, and it is impossible to refer the scales to the corresponding eggs. The length of the fish was recorded with the scale samples, and a tag attached to the egg samples also gives the length of the fish from which the sample was taken, but except in a few extreme instances this does not serve to identify the corresponding samples. Furthermore, the number of egg samples does not agree with the number of females. On account of this confusion of the records, a satisfactory analysis is impossible, and it has been necessary to handle the data for size of fish and size of eggs separately.

Table 26 (p. 87) gives the length-frequency distributions for the fish with ocean nuclei. In addition to these there were four fish with stream nuclei, all in their third year and averaging 64.5 cm. in length. Three of these were females.

Comparison with the data from the Columbia River and from Monterey shows that the average lengths of the various age groups, as found near Fort Bragg and Drakes Bay, is substantially in agreement with the data from other sources, although, as at Monterey, the fish are somewhat longer than Columbia River fish of the same age groups. The data are too few, however, to give accurate results.

Table 27 (p. 88) and Figure 25 give the egg sizes found in these collections. Sixty-four females are available, and the table shows that they are divided, on the basis of the size of the eggs, into three well-marked groups—the group with the largest eggs destined to mature during the year in which they were captured and the others composed of immature individuals. Sixty-seven per cent were mature. This is a somewhat smaller percentage of mature fish than was found off the mouth of the Columbia River at the same time of year. Since most of the individuals contained in this collection from the northern coast of California were taken in Drakes Bay, August 15 and 16, the comparison has been made with the Columbia River fish taken August 15. Reference to Figure 11 shows that on this date (the one hundred and seventh day of the season) about 87 per cent of the fish taken near the mouth of the Columbia were mature. The discrepancy can hardly be considered as significant, however, on account of the inadequate number of data from Drakes Bay and Fort Bragg.

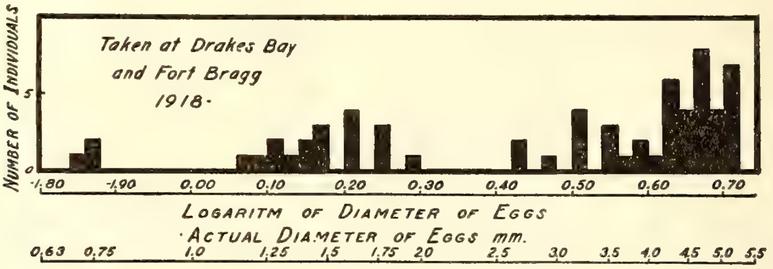

FIG. 25.—Distribution of egg sizes as found in a collection from Fort Bragg and Drakes Bay, Calif.

Since the egg samples were accompanied by data giving the length of the fish from which they were taken, and presumably, in the main, came from the same individuals from which scale samples were taken, an attempt has been made to determine which age groups were represented among the immature fish. A table has been prepared (Table 15) showing the correlation between length of fish and size of eggs, and also the range in the size of the fish composing the three groups distinguished by egg size. For the sake of comparison there is shown, in the same table, the range in size of the females found in the various age groups. From this table it is apparent that the fish with the smallest eggs were all in their second year. They were all between 40 and 50 cm. in length, and the only individuals of this size represented in the collection of scales were 2-year fish. The second group of fish (those with log *D* between 0.00 and 0.30) agree in length with those in their third year. There are 18 individuals in group 2, and in the scale collection 19 females were 3-year fish. The agreement between the two categories makes it seem practically certain that group 2 is composed largely, if not entirely, of fish in their third year with ocean nuclei. Group 3 (the mature individuals) is evidently composed mainly of fish in their fourth and fifth years.

TABLE 15.—*Chinook salmon taken by troll near Drakes Bay and Fort Bragg, Calif., July and August, 1918, tabulated to show correlation between size of eggs and length of fish*

Logarithm of diameter of eggs (mid-value of class)	Centimeter length (mid-value of class)							Total
	45	55	65	75	85	95	105	
1.85	3							3 (Group 1; 3 individuals).
.05			1	1				2 (Group 2; 18 individuals).
.15		1	4	2	1			8
.25			4		4			8
.45					3			3 (Group 3; 43 individuals).
.55				1	4	3	2	10
.65					5	10	8	23
.75						5	2	7
Total	3	1	9	4	17	18	12	64.
Group 1	3							3.
Group 2		1	9	3	5			18.
Group 3				1	12	18	12	43.

Females of scale collection tabulated according to length and age

	45	55	65	75	85	95	105	Total
Second year	3							3.
Third year			8	3	8			19.
Fourth year				1	2	17	10	30.
Fifth year							1	1.
Total	3		8	4	10	17	11	53.

SUMMARY AND CONCLUSIONS

1. It has been shown that the eggs of female chinook salmon undergo a well-marked differential growth during the growing period just preceding and terminating in the migration. As a result, those females which are destined to spawn during the year in which they are captured may be distinguished by the size of their eggs from those which will not mature for at least one more year.

2. Using the size of the eggs as a criterion, the commercial catch of salmon taken in the ocean near the mouth of the Columbia River has been analyzed and the percentage of mature and immature fish determined. It has been found that the percentage of mature fish taken in the ocean varies greatly during the season, being relatively small (from 10 to 20 per cent) in May but increasing gradually, until in August nearly 90 per cent are mature. While in general, as would be expected, fish taken within the Columbia River are mature, there are times when a few immature fish are taken by seines and traps in the extreme lower part of the estuary. The few data from Monterey and the northern coast of California are in substantial agreement with those from the region of the Columbia.

3. The immature fish taken in the ocean comprise, in the order of relative abundance, the following age groups: Third year, ocean nuclei; second year, ocean nuclei; third year, stream nuclei; fourth year, ocean nuclei; fourth year, stream nuclei; and fifth year, stream nuclei.

4. The relative abundance of fish with stream and with ocean nuclei has been considered, and it has been shown that about 22 per cent of the fish taken off the mouth of the Columbia River have scales with the stream type of nucleus. Since these fish are predominately from the Columbia River, this probably represents closely the percentage of fish of this category contained in the entire population.

5. Evidence is presented which shows that the more rigorous climatic conditions associated with higher latitudes and greater altitudes tend to increase the percentage of fish with stream nuclei—that is to say, more of the young fish remain in their home stream for at least one year after hatching.

6. Variations in size within the various age groups have been studied and a growth curve constructed. It has been found that the variations in the size of different races successively passing up the river on the spawning migration are such that data from this source can not be relied upon to show the growth. Similar variations among the fish taken in the ocean are, however, consistent, and may be depended upon to show the growth of the various age groups. Only this data has been used in constructing the growth curve.

7. The growth is typical of nearly all organisms in that it progresses at a maximum rate during the warmer part of the year—from May to September—and slows materially, if it does not stop entirely, during the colder months.

The undesirable features of the fishing for chinook salmon, which is carried on in the ocean by trolling and purse seining, are more or less obvious. A large percentage of immature fish are taken, which are far from having attained their maximum size and of relatively poor quality. They are feeding heavily, and the presence of large quantities of food in the stomach and intestines causes rapid spoiling. In many cases these immature fish are unfit for canning. On the other hand, the fish found in the river are, with very few exceptions, mature, and have definitely left their ocean feeding grounds and begun the long journey to the spawning beds. They have ceased feeding, and therefore growing, and the deterioration in the quality of flesh known to occur in salmon during their spawning migration will soon begin. Since the fish taken in the river have thus reached their maximum size and an optimum condition for commercial use, it seems logical that the commercial catch should be restricted to this stage in the life history.

From a business standpoint, the development of this ocean fishery would seem to be most undesirable. The poor quality of the outside fish, when canned, can not be questioned, and to continue to pack and market them as Columbia River chinook salmon can not fail to react unfavorably on the reputation of the Columbia River product. Many of the packers now place most of the fish taken outside in the inferior grades, marketing them as chums, but there is certain to be a constant tendency to place inferior fish with the better grades.

A much more important phase of the development of this outside fishery has to do with its effect on the conservation of the salmon run in the Columbia River. In order to understand this, however, it will be necessary to review briefly the recent history of the salmon industry in this district.

With slight fluctuations, which can not be referred definitely to any cause, the pack of chinook salmon on the Columbia River has remained fairly constant for the past 15 or 20 years. The opinion is current, however, that the run of salmon was low for the few years just preceding 1914, but in that year the run suddenly rose to normal again and was maintained at this higher level for a number of years. This erroneous opinion is the result of a common practice which considers only the canned product in discussing the trend of the productivity of the Columbia River. The figures for the canned pack alone support this contention but do not take into consideration the mild-curing industry, the development of which has had a marked effect on the production of canned salmon. Much of the mild-cured salmon was marketed in Europe and this market was suddenly closed by the opening of the World War in August, 1914. If this pack is calculated on the basis of cases of canned salmon and is added to the canned pack, the totals do not show a marked depression preceding 1914 nor a sudden rise in that year. There are fluctuations, of course, but there is nothing to show that they are systematic or other than "chance" variations.

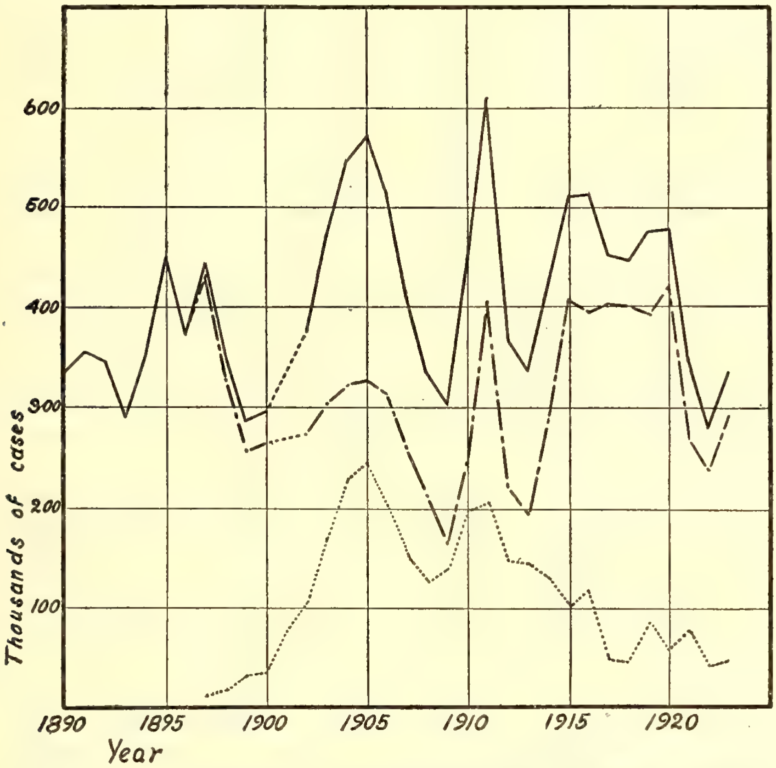

FIG. 26.—Pack of chinook salmon on the Columbia River, 1890 to 1923, inclusive. The mild-cured pack has been reduced to a basis of cases, one tierce being considered equal to 25 cases. Data from Cobb (1921) and Pacific Fisherman Year Book, 1924. Dotted line shows the mild-cure pack; broken line, the canned pack; and solid line, the total

This is apparent from Figure 26, which shows the number of cases of chinook salmon packed on the Columbia River from 1890 to 1923, both inclusive. The pack of mild-cured salmon is also shown, reduced to a basis of cases, and the total pack when these last data are added to the pack of canned salmon. The reduction of mild-cured salmon to a basis of cases has been made by considering that one tierce is the equivalent of 25 cases of canned fish. Published data are not available to show that this is a fair procedure, but it is believed that it gives a very close approximation to the truth. It is stated by Cobb (1921) that the loss in weight of mild-cured salmon "during the 2 or 3 weeks in which the fish lie in the first packing may be reckoned at 30 per cent." Packers on the Columbia River usually estimate that chinooks lose about 25 per cent of the round weight in cleaning preparatory to canning. Although the loss is probably a little more in the case of the fish that are mild cured, on account of the removal of the backbone, the figure is close enough for practical purposes. If, then, the weight of the cured fish is 70 per cent of the cleaned weight, and the cleaned weight is 75 per cent of the round weight, the total loss in weight during the entire process is 52.5 per cent of the round weight. It would therefore require 1,600 pounds of round fish to produce a tierce containing 830 pounds of mild-cured salmon. Canners on the Columbia River consider that it usually requires about 65 pounds of round fish to produce a case of canned fish, and on this basis 1,600 pounds would produce very close to 25 cases.

The Columbia River salmon fishery has for years been prosecuted with an intensity that makes it seem remarkable that a run of commercial value still remains. Figures, unfortunately, are not available to show how this intensity has increased since the beginning of the industry, but there can be no doubt that there has been a tremendous increase in the total fishing effort within the river. There has been not only an increase in the number of men, boats, and various units of gear, but a marked increase in the effectiveness with which the gear is employed. The motor boat has, within the last 20 years, replaced the slower sailboat, and the length of gill nets and seines and the size and effectiveness of fish wheels has increased. The fishing inside the river was, at the time the outside fishing first began, about as intensive as possible. Practically all good trap and wheel sites, seining grounds, and "drifts" in which gill nets could be operated were occupied. The discovery that salmon could be caught profitably outside the mouth of the river by trolling and in purse seines offered, therefore, a new avenue of expansion in which the fishermen so engaged did not come into direct and immediate competition with those already established on the fishing grounds in the river. It was found that the area in which such fishing could be carried on was wide, trollers ranging 20 to 30 miles in all directions from the mouth of the river. Such a broad region offered large possibilities for expansion and, since the outside fishing proved lucrative, it is not surprising that fishermen flocked to the new fields. Since this has not been accompanied by any appreciable reduction in the fishing effort within the river, it has meant a sudden and great increase in the total fishing effort directed against the salmon run of the Columbia River. Since a considerable portion of the total pack of salmon in the river has come from fish caught in the ocean, it means, further, that a correspondingly smaller percentage of the total pack has come from inside the mouth of the river from gill nets, seines, traps, and wheels.

From the evidence given above it is apparent that the immediate effect of the introduction of fishing methods that attack the immature fish found just off the mouth of the river is to increase the intensity of fishing, not only upon those salmon that are destined to mature and spawn during the year but also upon those that will form the spawning run the following year, and, to a more limited extent, the second year later. The full effect of the increased fishing effort during a given year will not, therefore, fall entirely upon that year but will be distributed over at least 3 years. Thus the outside fishing conducted in 1920 affected the run of mature fish into the river not only in 1920 but also in 1921 and 1922. Entirely apart from the fact that the young, immature fish produce an inferior product, this encroachment upon the runs of future years seems an especially vicious phase of this newly developed fishery. The full effect of the outside fishing is partially hidden; it is not immediately apparent in a decreased run into the river. It might, therefore, easily cause a very serious depletion before it became apparent that there was any danger of such an outcome.

At the same time other factors that have undoubtedly tended to reduce the supply of salmon have been at work. Many of the tributary streams that were once used as spawning beds by thousands of salmon are now blocked by dams of one sort or another, and other streams are made barren by the removal of quantities of water during the irrigation season. Large numbers of young salmon on their seaward migration become lost in the irrigation ditches or impounded in the pools left in the main stream as the water is drawn off for irrigation—where they die as the water warms and evaporates. On the whole, there is no question that the available spawning area in the Columbia River Basin has been materially reduced by such factors as these, and it seems probable that the encroachment on the spawning area will continue for some years to come. We have, then, a situation in which the continuance of the salmon is menaced on the one hand by a diminishing spawning area and on the other by an increased intensity of fishing. The various industrial and agricultural projects that are responsible for the erection of dams and irrigation ditches are of such importance that it is idle to suppose that they can long be opposed successfully by the interest of the salmon fishery. Regardless of right or wrong, it is inevitable that sooner or later the fisheries must disappear wherever they are directly and unavoidably opposed by the requirements of industrial and agricultural expansion.

Efforts to counteract the effect of these various agencies, all of which tend toward the destruction of the salmon, fall into three general categories: (1) Legal restrictions. These may affect the type or amount of gear used, the area open to fishing, and the time during which fishing may be conducted. (2) Construction of fishways over dams and of screens to irrigation ditches. (3) Artificial propagation.

The first of these is obviously designed to reduce the intensity of fishing. It is the oldest and still the most effective and indispensable of all means for conserving fishery resources. Unless a sufficient number of mature fish are permitted to ascend the rivers to the spawning areas, depletion is certain to occur regardless of any efforts that may be made in maintaining spawning areas or in reducing the mortality of the young fish by means of artificial propagation.

The construction and maintenance of fishways and screens to irrigation ditches is purely a palliative measure designed to offset in some measure the effect of encroaching civilization and development. They merely lessen to some extent the effect which the building of dams and irrigation ditches has in destroying spawning areas, and can not be expected fully to counteract the effect of this one destructive agency.

In artificial propagation we have a method designed to offset the work of destructive agencies, which is at once the hope and the despair of the scientific conservationist—the hope, in that it is so eminently logical to protect the young of the salmon during the early part of their life when the rate of mortality is high, and the despair, in that the evidence of its efficiency is inadequate and conflicting. Many instances can be adduced showing, apparently, the beneficial results of artificial propagation, but there are other instances in which no such results are to be observed. And if the extravagant claims of some of the proponents of artificial propagation were true we would long since have ceased to worry about the future of our salmon resources. The difficulty apparently lies in the fact that, as at present conducted, the procedure of artificial propagation is not based on scientific knowledge. With a gradual increase in the efficiency of hatchery procedure, which will come with placing it more and more on a truly scientific basis, we may hope that artificial propagation will come to be one of the most important factors in the preservation of our fishery resources. Noteworthy progress is being made by the Bureau of Fisheries toward this end, and it seems certain that the future development of artificial propagation is most promising. At the present time, however, it must be admitted that the importance of artificial propagation as a means of conserving the supply of salmon can not be accurately evaluated.

We are left, then, with the single alternative of maintaining the intensity of fishing below the danger point if the salmon run is to be preserved. Just what this point is no one can tell, and for that very reason it is essential to see that the intensity of fishing is kept down so as to provide what may be reasonably supposed to be a margin of safety. It is the duty of all who are interested in conservation to see that this is done—especially those officials whose duty it is so to administer the fisheries that depletion may not occur.

Just where do these facts fit into our discussion of the effect of the development of outside fishing on the supply of fish in the Columbia River? We have seen that the pack on the river has remained practically stationary for a number of years, during which time the intensity of fishing has been increased, especially by the addition of trolling and purse seining; that the spawning area is being gradually reduced; and finally, that a restriction of the amount of total fishing effort is essential to the maintenance of the run in the Columbia River.

It must always be an indication of danger if an appreciable increase in the intensity of fishing does not provide a corresponding increase in output. It must inevitably indicate that the productivity of a fishery is being maintained at a given level only by drawing to some extent upon the reserve stock needed for breeding if the race is to be maintained. Evidently a surplus of breeding adults is normally provided in nature, and it is only from this surplus that man can draw without immediately endangering the continuance of the supply. Any infringement upon the necessary breeding reserve is dangerous. A slight infringement may show no immediate effect, but if continued over a period of years the effect will be cumulative and is certain to end in disaster. The increase in fishing effort on the Columbia River by the development of trolling and purse seining has shown no corresponding increase in the total pack, and we may assume, therefore, that the present intensity of fishing is too great and is resulting in a dangerous reduction of the reserve of breeding adults. It may well, indeed, have been too great even before the outside fishing developed, in which case the new fishery is especially dangerous.

The intensity of fishing could, of course, be reduced by increasing restrictions on the gear used in the river, but this is hardly reasonable, since the outside fishery was the last to develop. It has further been shown that the outside fishing is uneconomical in that it takes the fish at a time when they are of poor quality and are much smaller than they would be at maturity, and that it is especially and subtly dangerous because it not only increases greatly the intensity of fishing but attacks the supply of fish one or two years before they become mature.

It is quite possible that these reasons are insufficient ones on which to base a legal restriction of this newly developed fishery, but if the run in the Columbia River is to be maintained we may be certain of one thing—if the outside fishing is not restricted, it will be a matter of a relatively short time only before the fishing in the river itself will have to be limited proportionally so as to supply the deficiency of spawning fish which is certain to result from the increased intensity of fishing caused by the development of trolling and purse seining. Efforts have been made to have restrictive legislation passed by the State legislatures of Oregon and Washington, but so far these efforts have met with only partial success. If it should prove impossible to prevent outside fishing entirely, it would seem desirable to limit such fishing to the latter part of the fishing season. This, at least, would reduce the number of immature fish taken, would tend to improve the quality of the pack, and would minimize to some extent the danger of seriously depleting the supply of fish before some indication of the imminence of such depletion has become apparent.

SUPPLEMENTARY TABLES

TABLE 16.—*Constants for each frequency distribution, Columbia River collections*

[F, female; M, male; S.D, standard deviation]

COLLECTIONS MADE INSIDE THE RIVER

Locality and date	Type of nucleus	Year class	Sex	Number	Length in centimeters		Logarithm of egg diameter	
					Mean	S. D.	Mean	S. D.
1. Ilwaco, May 10, 1919	Ocean	4	F	1	83.00		0.53	
	Stream	4	M	17	83.95			
			F	16	80.87		.531	
			Both	33	82.45±0.49	4.15±0.34		
		5	M	2	95.00			
			F	5	91.80		.582	
			Both	7	92.70			
2. Astoria ,May 13, 1919	Ocean	2	M	6	41.00			
		3	M	2	56.00			
		4	M	2	83.00			
			F	5	87.00		.574	
			Both	7	85.86			
	Stream	3	M	36	48.67± .53	4.70± .37		
		4	M	41	73.73± .61	5.80± .43		
			F	28	75.85± .60	4.74± .43	.498±0.0075	0.0598±0.0054
			Both	69	74.59± .46	5.64± .32		
		5	M	6	82.66			
			F	12	87.64		.57	
			Both	18	86.00			
		6	M	1	105.00			
3. Seufert, Oreg., May 16, 1919	Stream	4	M	74	75.00± .41	5.28± .29		
			F	77	74.74± .34	4.40± .24	.5713±.0039	.0502± .0027
			Both	151	74.87± .27	4.86± .19		
		5	M	10	96.80			
			F	22	93.64± .61	4.24± .43	.6718±.0062	.0430± .0044
			Both	32	94.62± .56	4.72± .40		

TABLE 16.—*Constants for each frequency distribution, Columbia River collections*—Continued

COLLECTIONS MADE INSIDE THE RIVER—Continued

Locality and date	Type of nucleus	Year class	Sex	Number	Length in centimeters		Logarithm of egg diameter	
					Mean	S. D.	Mean	S. D.
4. Ilwaco, May 17 and 18, 1920 (from gill nets and traps).	Ocean	4	M	2	84.00			
			F	1	97.00		0.63	
			Both	3	88.33			
		5	M	1	111.00			
			F	1	93.00		.67	
			Both	2	102.00			
	Stream	4	M	3	66.33			
			F	3	78.33		.5366	
			Both	6	72.33			
		5	M	14	101.28			
			F	29	94.45±1.03	8.25±0.73	[1] .5804±0.0078	0.0600±0.0055
			Both	43	96.67± .87	8.48± .62		
5. Chinook, May 27, 1919 (from traps in Baker Bay).	Ocean	2	M	1	51.00			
		4	M	3	82.30			
			F	12	83.30		.572	
			Both	15	83.10			
			M	1	125.00			
	Stream	3	M	1	49.00			
		4	M	11	81.60			
			F	4	83.50		.584	
			Both	15	82.30			
		5	F	9	86.40		.595	
		6	F	2	93.00		.620	
6. Dodson, May 30 and 31, 1919 (from wheels and seines).	Ocean	2	M	4	46.50			
		3	M	1	65.00			
	Stream	3	M	11	49.90			
		4	M	34	77.29±1.01	8.78± .72		
			F	26	78.23± .96	7.30± .68	.5977± .0092	.0693± .0065
			Both	60	77.70± .71	8.18± .50		
		5	M	1	101.00			
			F	5	97.00		.6930	
			Both	6	97.80			
		6	M	1	111.00			
7. Ilwaco, June 10, 1919 (from gill nets).	Ocean	5	F	5	101.00		.550	
		6	M	2	114.00			
	Stream	4	M	3	82.33			
			F	2	84.00		.650	
			Both	5	83.00			
		5	M	3	108.00			
			F	4	94.50		.700	
			Both	7	100.30			
		6	M	1	123.00			
8. Seufert, June 16, 1919	Ocean	3	M	1	61.00			
		5	M	3	111.00			
			F	4	108.00		.565	
			Both	7	109.30			
		6	M	1	123.00			
			F	1	115.00		.53	
			Both	2	119.00			
	Stream	3	M	10	52.60			
		4	M	21	76.52±1.16	7.86± .82		
			F	26	81.54±1.03	7.76± .73	.6569± .0093	.0696± .0065
			Both	47	79.30± .81	8.20± .57		
		5	M	10	103.80			
			F	18	101.56± .96	6.06± .68	.6500± .0160	.1010± .0113
			Both	28	102.36± .76	6.00± .54		
		6	M	3	115.60			
			F	1	109.00		.51	
			Both	4	114.00			
9. Warrendale, June 16 and 17, 1919 (wheels and seines).	Ocean	3	M	1	67.00			
		4	F	1	91.00		.43	
		5	M	10	114.60			
			F	10	108.80		.538	
			Both	20	111.70± .89	5.9 ± .63		
	Stream	3	M	11	54.64			
		4	M	50	72.92± .72	7.5 ± .51		
			F	17	81.35±1.03	6.3 ± .73	.6324± .0087	.0530± .0061
			Both	67	75.06± .66	8.08± .47		
		5	M	6	102.00			
			F	20	96.00± .76	5.02± .54	.6910± .0075	.0496± .0053
			Both	26	98.00± .86	6.50± .61		
		6	M	1	123.00			

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[1] Calculated for 27 mature specimens. For one other log *D* was 0.11; for another, 0.29.

TABLE 16.—*Constants for each frequency distribution, Columbia River collections*—Continued

COLLECTIONS MADE INSIDE THE RIVER—Continued

Locality and date	Type of nucleus	Year class	Sex	Number	Length in centimeters		Logarithm of egg diameter	
					Mean	S. D.	Mean	S. D.
10. Astoria, June 24 and 25, 1919 (seines).	Ocean	2	M	2	50.00			
		3	M	8	60.50			
		4	M	3	79.60			
			F	11	81.50		0.588	
			Both	14	81.10			
		5	M	2	112.00			
			F	3	96.20		.510	
			Both	5	102.50			
		6	M	1	123.00			
			F	4	106.00		.550	
			Both	5	109.50			
	Stream	3	M	3	49.60			
		4	M	8	77.30			
			F	5	84.20		.618	
			Both	13	79.90			
		5	F	3	95.00		.683	
		6	F	1	101.00		.550	
11. Ilwaco, July 3, 1919 (traps).	Ocean	3	F	1	71.00		.5100	
		4	F	24	83.58±0.54	3.93±0.38	.5900±0.0046	.0332±0.0032
		5	F	17	99.94±1.12	6.82±.79	.6029±.0062	.0381±.0044
		6	F	3	108.30		.6570	
	Stream	3	F	1	59.00		.0100	
		4	F	4	85.50		.5950	
		5	F	1	89.00		.6300	
12. Sand Island, July 7, 1919 (seines).	Ocean	2	M	21	43.38±.51	3.46±.36		
			F	5	48.60		$\bar{1}$.902	
			Both	26	44.38±.53	4.04±.38		
		3	M	3	57.67			
			F	2	71.00		One 0.11 and another 0.51	
			Both	5	63.00			
		4	M	2	87.00			
			F	20	83.30±.92	6.10±.65	0.5880±.0047	.0309±.0033
			Both	22	83.54±.90	6.24±.63		
		5	M	10	104.20			
			F	8	100.00		.5925	
			Both	18	102.33±1.34	8.42±.95		
		6	M	2	121.00			
	Stream	3	M	5	48.60			
			F	4	48.00		$\bar{1}$.850	
			Both	9	48.30			
		4	M	1	63.00			
			F	1	83.00		0.63	
			Both	2	73.00			
		5	F	1	89.00		.69	
13. Warrendale, July 16, 1919 (wheels).	Ocean	2	M	36	41.55±.53	4.72±.37		
		3	M	29	60.58±.63	5.04±.45		
			F	2	72.00		.60	
			Both	31	61.32±.68	5.63±.48		
		4	M	25	83.24±1.15	8.50±.81		
			F	19	79.95±.89	5.79±.63	.6247±.0072	.0466±.0051
			Both	44	81.82±.78	7.63±.55		
		5	M	10	106.40			
			F	18	97.67±1.10	6.95±.78	.6555±.0074	.0466±.0052
			Both	28	100.78±1.19	9.33±.84		
		6	M	3	119.00			
		3	M	28	57.50±.48	3.8 ±.34		
		4	M	6	79.40			
			F	4	82.00		.66	
			Both	10	80.40			
		5	F	2	90.00		.68	
		6	F	1	103.00		.67	
14. Ilwaco, July 28, 1919 (traps)	Ocean	3	M	2	63.00			
		4	M	13	87.48			
			F	8	89.74		.65	
			Both	21	88.33±1.33	9.12±.95		
		5	M	10	108.80			
			F	15	96.88		.658	
			Both	25	101.64±1.14	8.48±.81		
		6	M	1	113.00			
	Stream	4	M	1	72.50			

TABLE 16.—*Constants for each frequency distribution, Columbia River collections*—Continued

COLLECTIONS MADE INSIDE THE RIVER—Continued

Locality and date	Type of nucleus	Year class	Sex	Number	Length in centimeters		Logarithm of egg diameter	
					Mean	S. D.	Mean	S. D.
15. Seufert, Aug. 5, 1919 (wheels).	Ocean	2	M	5	39.30			
		4	M	4	84.00			
			F	4	77.50		0.662	
			Both	8	80.75			
		5	M	3	109.50			
			F	1	99.00		.721	
			Both	4	106.90			
		6	M	1	125.00			
	Stream	2	M	1	26.50			
		3	M	3	49.50			
		4	M	1	87.50			
		5	M	1	103.00			
16. Dodson, Aug. 6, 1919 (seines).	Ocean	2	M	10	41.80			
		3	M	6	60.34			
		4	M	23	[2] 90.04			
			F	21	[2] 84.72		.6824±0.0047	0.0323±0.0033
			Both	44	[2] 87.44			
		5	M	15	107.26			
			F	13	97.46		.6778	
			Both	28	102.71±0.93	7.28±0.66		
	Stream	3	M	3	55.00			
		4	F	3	85.00		.6833	
		5	F	1	99.00		.7100	
17. Astoria, Aug. 22, 1919 (seines).	Ocean	2	M	1	49.00			
		3	M	13	77.30			
			F	8	82.50		.7426	
			Both	21	79.28±1.42	9.66±1.00		
		4	M	37	See text, p. 53, and Table 19.			
			F	25			.7316± .0098	.0730± .0069
			Both	62				
		5	F	3	90.33		.7100	
	Stream	4	M	2	77.00			
			F	3	87.67		.7033	
			Both	5	83.50			
		5	F	1	89.00		.71	
		6	F	1	103.00		.59	
18. Astoria, Sept. 12, 1919 (seines).	Ocean	3	M	14	70.29			
			F	7	78.80		.7614	
			Both	21	73.10±1.31	8.94± .93		
		4	M	35	See text, p. 53, and Table 20.			
			F	21			.8233± .0076	.0550± .0053
			Both	56				
		5	M	2	112.00			
			F	4	93.00		.8100	
			Both	6	99.30			
	Stream	4	F	3	87.70		.8167	
		5	M	1	103.00			
			F	3	92.30		.7967	
			Both	4	95.00			
		6	M	4	105.00			
			F	1	103.00		.7500	
			Both	5	104.60			
COLLECTIONS OF FISH TAKEN IN THE OCEAN BY TROLL UNLESS OTHERWISE STATED								
19. May 8 to 10, 1919	Ocean	2	M	17	44.53±0.61	3.72±0.43		
			F	19	43.10± .50	3.26± .36	$\bar{1}$.8100±0.0085	0.0548±0.0060
			Both	36	43.78± .40	3.57± .27		
		3	M	51	62.41± .51	5.43± .36		
			F	102	61.00± .38	5.68± .27	[3] 0.1042± .0034	.0500± .0024
			Both	153	61.46± .31	5.64± .22		
		4	M	3	80.33			
			F	18	79.56± .71	4.46± .50	.3174	
			Both	21	79.67± .63	4.25± .44		
		5	F	1	93.00		.3900	
	Stream	3	M	34	49.06± .43	3.74± .31		
			F	18	48.11± .59	3.72± .42	$\bar{1}$.9588± .0092	.0580± .0065
			Both	52	48.73± .35	3.76± .25		
		4	M	2	66.00			
			F	2	74.00		0.3800	
			Both	4	70.00			
		5	F	3	85.67		.5300	
		6	F	2	95.00		.5800	

[2] The distributions were so irregular and, especially in the case of the males, suggestive of bimodality, that it seemed useless to calculate the standard deviation and the probable errors until a more detailed study can be made.

[3] Excluding 2 individuals with log *D* greater than 0.30. (See p. 34.)

Table 16.—*Constants for each frequency distribution, Columbia River collections*—Continued

COLLECTIONS OF FISH TAKEN IN THE OCEAN BY TROLL UNLESS OTHERWISE STATED—Contd

Locality and date	Type of nucleus	Year class	Sex	Number	Length in centimeters		Logarithm of egg diameter	
					Mean	S. D.	Mean	S. D.
20. May 18, 1920	Ocean	3	M	64	71.16±0.40	4.74±0.28		
			F	39	70.74± .57	5.25± .40	(See Table 21.)	
			Both	103	71.00± .33	4.95± .23		
		4	M	29	84.52± .97	7.73± .68		
			F	36	83.00± .63	5.66± .45	(See Table 21.)	
			Both	65	83.68± .56	6.70± .40		
		5	M	20	99.60±1.22	8.12± .87		
			F	13	96.15		0.4054	
			Both	33	98.09± .92	7.84± .65		
	Stream	4	M	15	73.80			
			F	13	76.54		(See Table 21.)	
			Both	28	75.07± .79	6.18± .56		
		5	M	8	87.40			
			F	6	89.70		.4333	
			Both	14	88.40			
21. May 24, 1919	Ocean	2	M	3	46.30			
			F	4	43.50		$\bar{1}$.8000	
			Both	7	44.70			
		3	M	5	66.20			
			F	8	62.50		[4]0.0980	
			Both	13	63.90			
		4	M	3	77.00			
			F	3	77.70		.2567	
			Both	6	77.30			
	Stream	3	M	3	53.60			
			F	1	61.00		.0700	
			Both	4	55.50			
22. June 4, 1919	Ocean	2	M	11	46.45			
			F	18	44.78± .45	2.81± .32	$\bar{1}$.8280±0.0178	0.0756±0.0137
			Both	29	45.41± .34	2.69± .24		
		3	M	25	63.40± .82	6.09± .58		
			F	32	61.61± .59	5.05± .42	0.0981± .0056	.0474± .0040
			Both	57	62.38± .49	5.60± .37		
		4	M	3	84.30			
			F	1	83.00		.25	
			Both	4	84.00			
		5	F	1	99.00		.45	
	Stream	2	M	1	37.00			
		3	M	11	52.80			
			F	11	50.40		$\bar{1}$.948	
			Both	22	51.66± .60	4.10± .43		
		4	F	4	75.50		0.255	
		5	M	1	91.00			
			F	1	81.00		.270	
			Both	2	86.00			
23. June 10, 1919	Ocean	2	M	7	47.20			
			F	3	50.60		$\bar{1}$.931	
			Both	10	48.22			
		3	M	3	63.30			
			F	3	72.00		0.169	
			Both	6	67.70			
		4	M	1	97.00			
			F	1	92.00		.681	
			Both	2	94.50			
	Stream	3	M	4	53.00			
			F	2	47.00		$\bar{1}$.919	
			Both	6	51.00			
24. June 21, 1919	Ocean	2	M	4	48.00			
			F	6	46.30		$\bar{1}$.845	
			Both	10	47.00			
		3	M	11	67.80			
			F	4	72.50		(5)	
			Both	15	69.12			
		4	M	10	85.40			
			F	10	86.40		0.510	
			Both	20	58.90±1.16	7.72± .82		
		5	F	2	97.00		.550	
	Stream	3	M	8	54.70			
			F	4	54.50		.000	
			Both	12	54.60			
		4	M	2	82.00			
			F	5	81.80		.586	
			Both	7	81.86			
		5	F	1	95.00		.690	

[4] Exclusive of 1 individual with large eggs; log *D* greater than 0.30.

[5] Two individuals had small eggs, log *D* 0.10, and two had large eggs, log *D* 0.50.

TABLE 16.—*Constants for each frequency distribution, Columbia River collections*—Continued

COLLECTIONS OF FISH TAKEN IN THE OCEAN BY TROLL UNLESS OTHERWISE STATED—Contd.

Locality and date	Type of nucleus	Year class	Sex	Number	Length in centimeters		Logarithm of egg diameter	
					Mean	S. D.	Mean	S. D.
25. June 25, 1919 (purse seines)	Ocean	2	F	3	45.50	----------	$\bar{1}.8990$	----------
		3	M	1	65.00	----------	----------	----------
		4	M	1	88.50	----------	----------	----------
			F	2	83.50	----------	0.5430	----------
			Both	3	85.20	----------	----------	----------
	Stream	3	M	1	56.50	----------	----------	----------
			F	1	46.00	----------	$\bar{1}.9590$	----------
			Both	2	51.20	----------	----------	----------
		4	M	1	83.00	----------	----------	----------
			F	1	79.00	----------	0.5610	----------
			Both	2	81.00	----------	----------	----------
26. July 2, 1919	Ocean	2	F	14	49.30	----------	$\bar{1}.8730$	----------
		3	F	31	67.45± .69	5.72±0.49	[6] 0.1085±0.0052	0.0396±0.0037
		4	F	23	83.78± .90	6.37± .63	[7] .5336± .0116	.0805± .0082
		5	F	11	95.40	----------	.5792	----------
	Stream	3	F	7	55.00	----------	.0214	----------
		4	F	10	79.60	----------	[8] .4340	----------
		5	F	3	88.40	----------	.5300	----------
27. July 28, 1919	Ocean	2	F	3	55.67	----------	$\bar{1}.9100$	----------
		3	F	16	71.01	----------	[9] 0.1531	----------
		4	F	49	89.33± .64	6.64± .45	.6406± .0059	.0618± .0042
		5	F	18	96.22± .75	4.72± .53	.6733± .0094	.0594± .0067
		6	F	1	103.00	----------	.6900	----------
	Stream	3	F	7	59.00	----------	.0756	----------
		4	F	3	82.33	----------	[10] .6800	----------
		5	F	1	87.00	----------	.6100	----------
28. Aug. 3-5 and 25, 1914 (selected as "grilse").	Ocean	2	M	35	51.91± .51	4.47± .36	----------	----------
			F	38	51.37± .36	3.35± .25	----------	----------
			Both	73	51.63± .30	3.80± .21	----------	----------
		3	F	2	62.00	----------	----------	----------
	Stream	2	M	2	40.00	----------	----------	----------
		3	M	4	56.50	----------	----------	----------
			F	12	57.50	----------	----------	----------
			Both	16	57.25	----------	----------	----------
29. Aug. 13, 1919	Ocean	2	F	2	57.00	----------	$\bar{1}.9300$	----------
		3	F	15	78.60	----------	[11] 0.7210	----------
		4	F	66	93.00± .62	7.48± .43	[12] .7243± .0060	.0706± .0042
		5	F	4	103.00	----------	.7800	----------
	Stream	3	F	1	59.00	----------	.0300	----------
		4	F	7	81.00	----------	[13] .6767	----------
30. Aug. 13-17, 1918 (five taken in September).	Ocean	2	F	5	53.00	----------	$\bar{1}.9500$	----------
		3	F	25	86.60±1.04	7.70± .74	[14] 0.7580± .0035	.0235± .0024
		4	F	20	95.30± .98	6.50± .69	[15] .7426± .0127	.0820± .0090
		5	F	19	100.16± .99	6.40± .70	.7553± .0121	.0784± .0086
	Stream	3	F	2	66.00	----------	.1300	----------
		4	F	3	87.00	----------	.7170	----------
		5	F	27	95.59± .77	5.96± .55	.7811± .0043	.0332± .0030
		6	F	1	95.00	----------	.7500	----------
31. Sept. 18 and 19, 1919	Ocean	2	M	5	52.20	----------	----------	----------
			F	2	56.00	----------	.0000	----------
			Both	7	53.30	----------	----------	----------
		3	M	7	75.28	----------	----------	----------
			F	7	70.72	----------	.1500	----------
			Both	14	73.00	----------	----------	----------
		6	M	1	103.00	----------	----------	----------
			F	1	99.00	----------	.7700	----------
			Both	2	101.00	----------	----------	----------
		3	M	1	55.00	----------	----------	----------
			F	2	66.00	----------	.1000	----------
			Both	3	62.33	----------	----------	----------
		4	M	3	91.00	----------	----------	----------
		5	M	1	103.00	----------	----------	----------

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[6] Exclusive of 5 individuals, for which log *D* was 0.4340.
[7] Exclusive of 1 individual, for which log *D* was 0.1900.
[8] Exclusive of 3 individuals, for which log *D* was 0.1766.
[9] Exclusive of 3 individuals, for which log *D* was 0.6167.
[10] Exclusive of 1 individual, for which log *D* was 0.2500.
[11] Exclusive of 6 individuals, for which log *D* was 0.1430.
[12] Exclusive of 3 individuals, for which log *D* was 0.3030.
[13] Exclusive of 1 individual, for which log *D* was 0.2700.
[14] Exclusive of 4 individuals, for which log *D* was 0.1600.
[15] Exclusive of 1 individual, for which log *D* was 0.2500.

TABLE 17.—*Chinooks taken in wheels in the Columbia River near Warrendale, Oreg., July 16, 1919*

Females tabulated according to size of eggs, type of nucleus, and age

Logarithm of diameter of eggs (mid-value of class)	Ocean nuclei			Stream nuclei			Total
	Third year	Fourth year	Fifth year	Fourth year	Fifth year	Sixth year	
0.55		1	1				2
.57		4	1				5
.59	1	2		1			4
.61	1	2	1				4
.63		2	4				6
.65		2	2				4
.67		4	2	1	1	1	9
.69		1	3	2	1		7
.71		1	4				5
Total	2	19	18	4	2	1	46
Mean	0.60	0.6247±0.0072	0.6555±0.0074	0.66	0.68	0.67	
Standard deviation		.0466± .0051	.0466± .0052				

TABLE 18.—*Chinooks taken by troll off the mouth of the Columbia River, July 28, 1919, collected at Ilwaco, Wash. Females only*

Tabulated according to size of eggs, type of nucleus, and age [1]

Logarithm of diameter of eggs (mid-value of class)	Ocean nuclei				Stream nuclei		Total
	Second year	Third year	Fourth year	Fifth year	Third year	Fourth year	
$\bar{1}.81$	1						1
.95*	1						1
.97	1						1
0.03*					1		1
.05		1			1		2
.07					2		2
.09					1		1
.11		1			2		3
.13		2					2
.15		2					2
.17		4					4
.19		2					2
.21		1					1
.25*						1	1
.51**			1				1
.53							
.55			2				2
.57		1	3				4
.59			6	1			7
.61			6	3			9
.63		1	11	3			15
.65		1	6	3		1	11
.67			4				4
.69			4	2			6
.71				1		1	2
.73			2	2			4
.75			1	1			2
.77			1	1			2
.79			1	1			2
.81							
.83			1				1
Total	3	16	49	18	7	3	96
Mean	$\bar{1}.91$	Immature 0.1531 Mature .6167	0.6406±0.0059	0.6733±0.0094	0.0756	Immature 0.25 Mature .68	
Standard deviation			.0618± .0042	.0594± .0067			

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[1] Two specimens, one a 5-year fish with the stream type of nucleus and one a 6-year fish with the ocean type of nucleus, are omitted from the table. The logarithm of the diameter of the eggs in the case of the 5-year fish was 0.61, and for the 6-year fish 0.69.

TABLE 19.—*Chinook salmon taken by seines on the lower Columbia River, collected at Astoria, Oreg., August 22, 1919*

Tabulated according to length, type of nucleus, age and sex[1]

Centimeter length (mid-value of class)	Ocean nuclei								Stream nuclei				Total
	Second year	Third year			Fourth year			Fifth year	Fourth year			Fifth year	
	Male	Male	Female	Total	Male	Female	Total	Female	Male	Female	Total	Female	
49	1												1
53*		1		1									1
65*		1		1									1
67					1		1						1
69		2		2	1		1						3
71					1		1						1
73		2		2	1		1						3
75			1	1	4		4		1		1		6
77		1	1	2	4		4						6
79			1	1	2	3	5		1		1		7
81		1		1	2	4	6						7
83		1	1	2	1	1	2						4
85			1	1	1	3	4						5
87			3	3	1		1	1		2	2		7
89		1		1				1		1	1	1	4
91		3		3	2	1	3						6
93						1	1						1
95						3	3	1					4
97					2	3	5						5
99					2	2	4						4
101					3	4	7						7
103					4		4						4
105					1		1						1
107					2		2						2
109					2		2						2
Total	1	13	8	21	37	25	62	3	2	3	5	1	93
Mean	49.0	77.30	82.50	79.28±1.42	(2)	(2)	(2)	90.33	77.00	87.67	83.50	89.00	
Standard deviation				9.66±1.00									

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[1] In addition to the specimens tabulated above there was 1 female 103 cm. long, in its sixth year, stream nucleus.

[2] The apparent bimodality of the distributions of the 4-year fish has been discussed on page 53. The various averages and standard deviations are as follows: (1) Fish less than 90 cm. in length—males (19 specimens), mean, 77.00±0.77, standard deviation, 4.98±0.55; females (11 specimens), mean, 81.73; total (30 sepcimens), mean, 78.74±0.59, standard deviation, 4.78±0.43. (2) Fish greater than 90 cm. in length—males (18 specimens), mean, 101.44±0.81; standard deviation, 5.10±0.57; females (14 specimens), mean, 97.30; total (32 specimens), mean, 99.62±0.57, standard deviation, 4.80±0.41.

TABLE 20.—*Chinook salmon taken in beach seines on the lower Columbia River collected at Astoria, Oreg., September 12, 1919*

Tabulated according to length, type of nucleus, age, and sex

Centimeter length (mid-value of class)	Ocean nuclei									Stream nuclei							Total
	Third year			Fourth year			Fifth year			Fourth year	Fifth year			Sixth year			
	Male	Female	Total	Male	Female	Total	Male	Female	Total	Female	Male	Female	Total	Male	Female	Total	Total
57	1		1														1
61*	1		1														1
63		1	1														1
65	3		3														3
69*	4		4		1	1											5
71	1	1	2														2
73				3		3											3
75	1		1	4		4											5
77				4		4											4
79	1	1	2	3	1	4											6
81		1	1	1	3	4											5
83	1		1	2	1	3											4
85		2	2	2	4	6		2	2	1							11
87	1	1	2							1		1	1				4
89				1		1											1
91				1		1				1							2
93					3	3											3
95				3	2	5						2	2	1		1	8
97					1	1											1
99					2	2											2
101				1	2	3		2	2								5
103				2		2					1		1	1	1	2	5
105				5	1	6								1		1	7
109*				2		2											2
111							1		1								1
113							1		1								1
115				1		1											1
117														1		1	1
Total	14	7	21	35	21	56	2	4	6	3	1	3	4	4	1	5	95
Mean	70.29	78.80	73.10±1.31	(1)	(1)	(1)	112.00	93.00	99.30	87.7	103.00	92.30	95.00	105.00	103.00	104.60	---
Standard deviation			8.94± .93														---

[1] The two types (small and large) of 4-year fish with ocean nuclei have been separated, as was done in Table 19. (See p. 53.) The means and standard deviations are as follows: (1) Fish less than 90 cm. in length—males (20 specimens), mean, 78.50±0.66, standard deviation, 4.42±0.47; females (10 specimens), mean, 81.40; total (30 specimens), mean, 79.53±0.56, standard deviation, 4.55±0.41. (2) Fish greater than 90 cm. in length—males (15 specimens), mean, 102.76; females (11 specimens), mean, 97.37; total (26 specimens), mean, 100.46±0.78, standard deviation, 5.94±0.55.

TABLE 21.—*Chinooks taken by troll near the mouth of the Columbia River, collected at Ilwaco, Wash., May 18, 1920*

Females tabulated according to size of eggs, type of nucleus, and age

Logarithm of diameter of eggs (mid-value of class)	Ocean nuclei			Stream nuclei		Total
	Third year	Fourth year	Fifth year	Fourth year	Fifth year	
0.05	1					1
.07	2					2
.11*	3					3
.13	8					8
.15	7					7
.17	4			1		5
.19	3					3
.21	1	1		1		3
.23	1	4		3		8
.25		5	1	1		7
.27	1	3				4
.29		1		1	1	3
.31			1			1
.33	1	1				2
.35	1	2	1	1		5
.37	1	5	1			7
.39	1	2	1	2		6
.41	1	1	4		1	7
.43	2	2		1	3	8
.45	1	3	2	1		7
.47		2				2
.49		1		1		2
.51			1			1
.55*		3	1			4
.61*					1	1
Total	39	36	13	13	6	107
Mean	(1)	(2)	0.4054	(3)	0.4333	

[1] Group with log *D* less than 0.30, mean is 0.1474± 0.0053; standard deviation is 0.0444±0.0038. Group with log *D* greater than 0.30, mean is 0.395.

[2] Group with log *D* less than 0.30, mean is 0.2486. Group with log *D* greater than 0.30, mean is 0.4254±0.0095; standard deviation is 0.0658±0.0067.

[3] Group with log *D* less than 0.30, mean is 0.2300. Group with log *D* greater than 0.30, mean is 0.4167.

TABLE 22.—*Chinook salmon taken by troll in Monterey Bay, Calif., June 16, 1915*

Tabulated according to length, type of nucleus, age, and sex

Centimeter length (mid-value of class)	Ocean nuclei								
	Second year			Third year			Fourth year		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
47	1	1	2						
49	2	1	3						
51	7	2	9						
53	2	2	4						
55	3	1	4						
57	5		5						
59	2		2						
63*	1		1						
67*					1	1			
69				2		2			
71				2	1	3			
73				3	4	7			
75				3		3			
77				2		2	1		1
79				1	3	4			

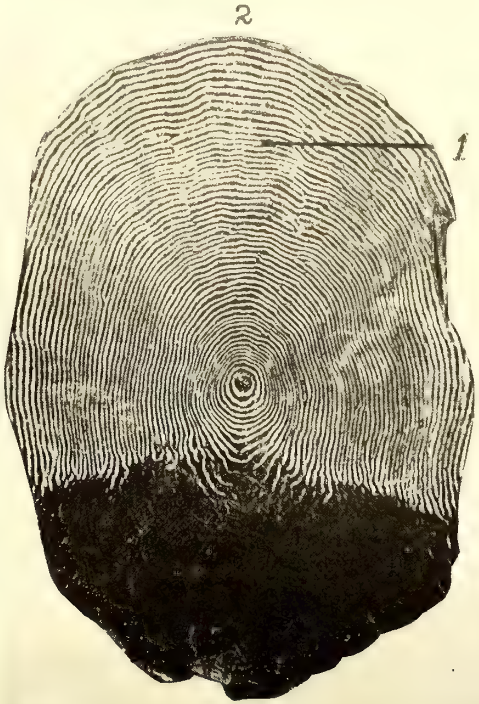

FIG. 27.—Chinook salmon in its second year, ocean nucleus, immature. Female, 51 cm., log. *D* 1.91. Taken by troll off the mouth of the Columbia River, June 4, 1919. ×20

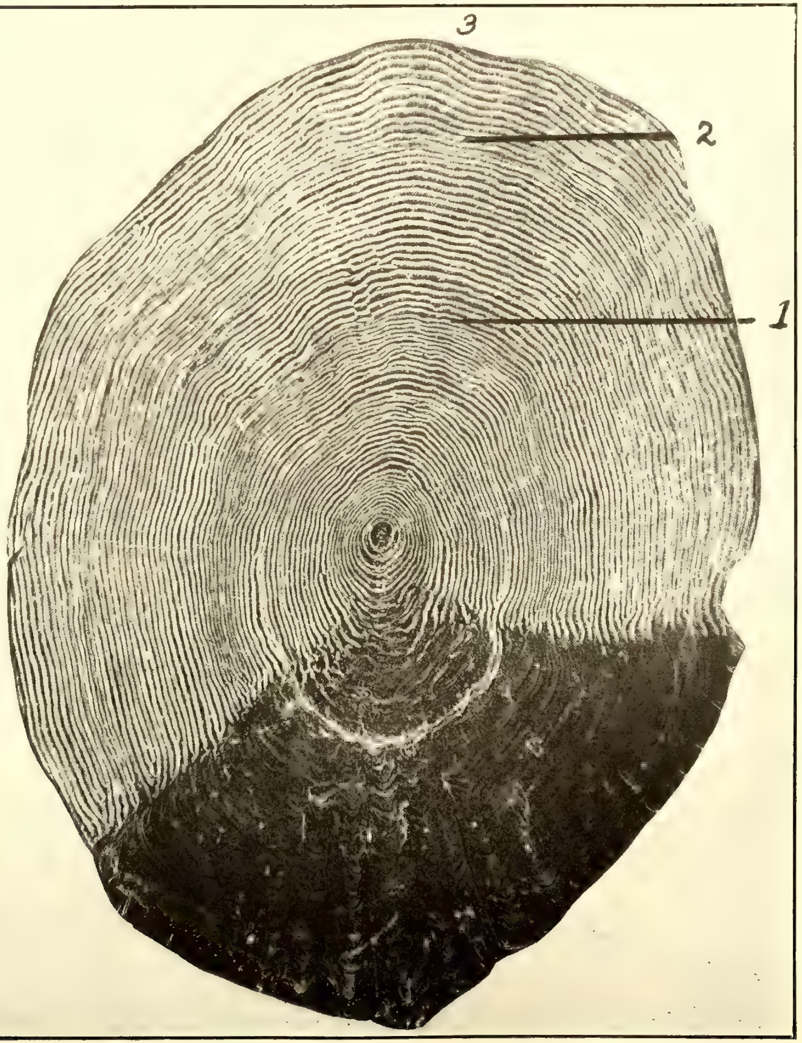

FIG. 28.—Chinook salmon in its third year, ocean nucleus, immature. Female, 67 cm., log. *D* 0.113. Taken by troll off the mouth of the Columbia River, July 2, 1919. ×20

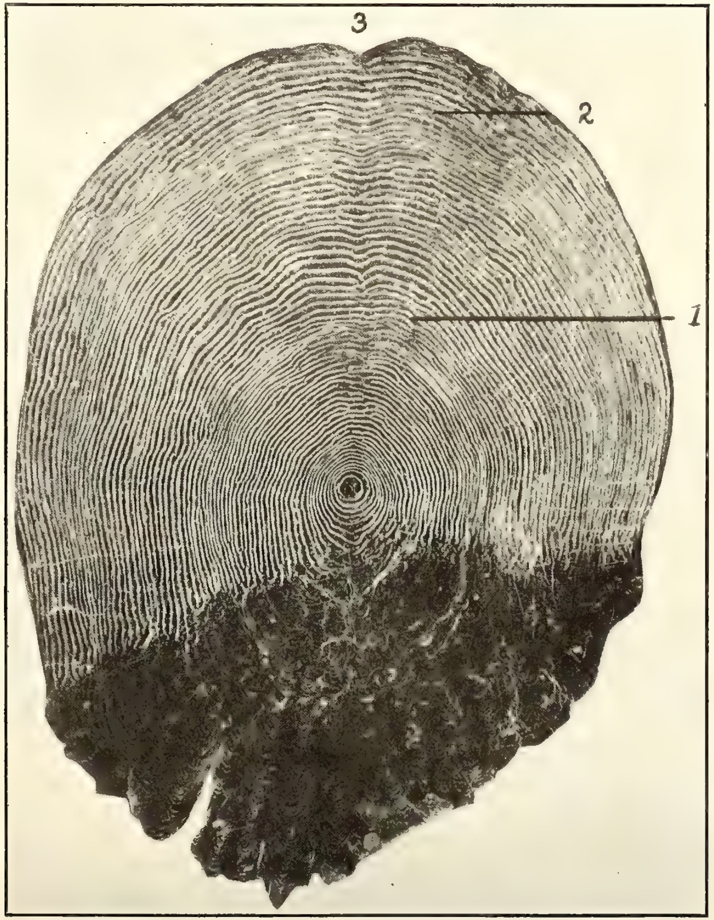

FIG. 29.—Chinook salmon in its third year, ocean nucleus, mature. Female, 66 cm., log. *D* 0.431. Taken by troll off the mouth of the Columbia River, July 2, 1919. ×20

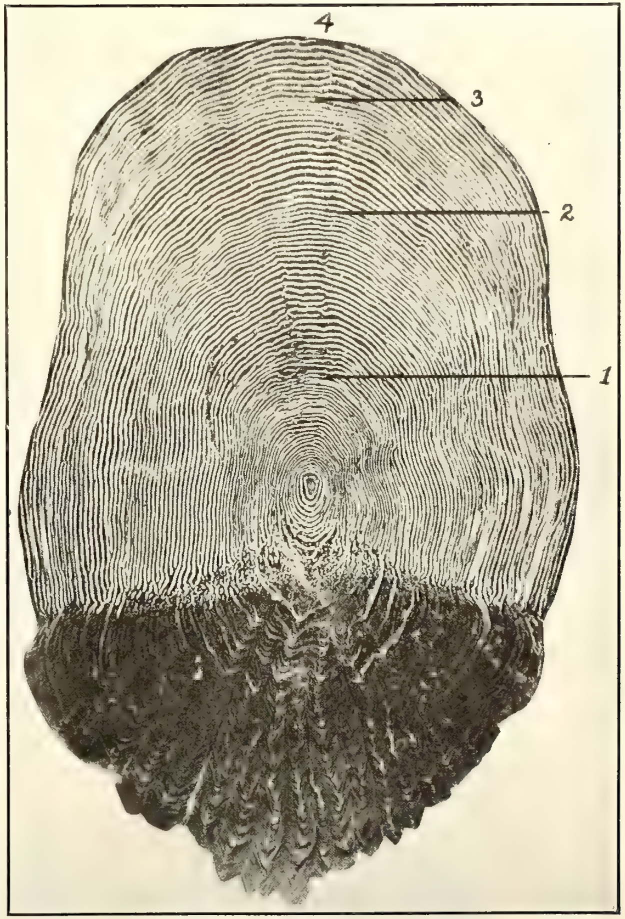

FIG. 30.—Chinook salmon in its fourth year, ocean nucleus, immature. Female, 80 cm., log. *D* 0.281. Taken by troll off the mouth of the Columbia River, August 13, 1919. ×20

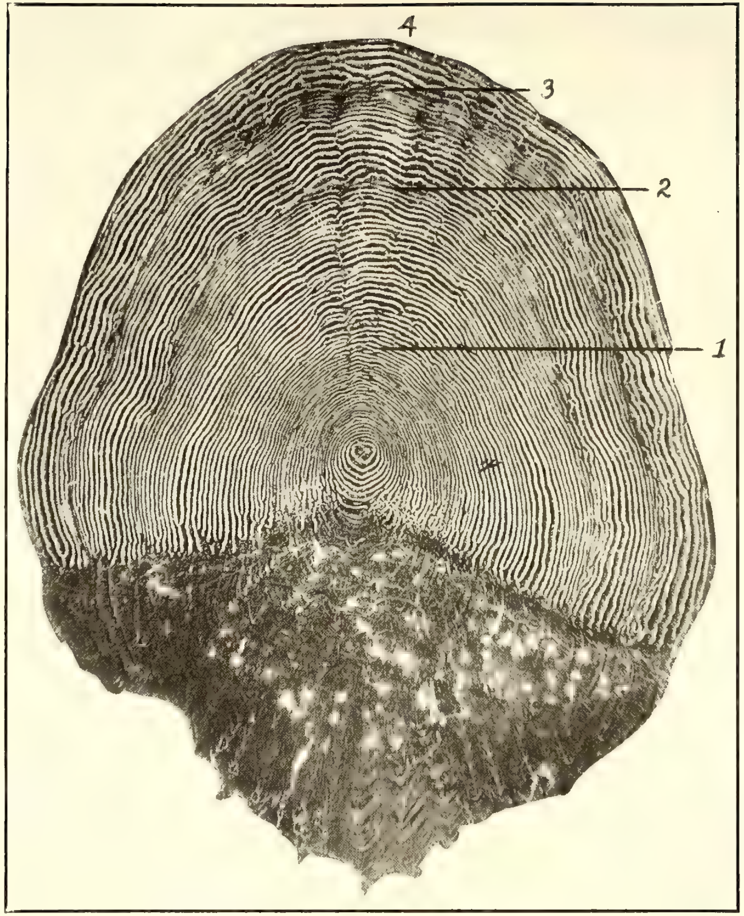

FIG. 31.—Chinook salmon in its fourth year, ocean nucleus, mature. Female, 77 cm., log. *D* 0.643. Taken by troll off the mouth of the Columbia River, August 13, 1919. ×20

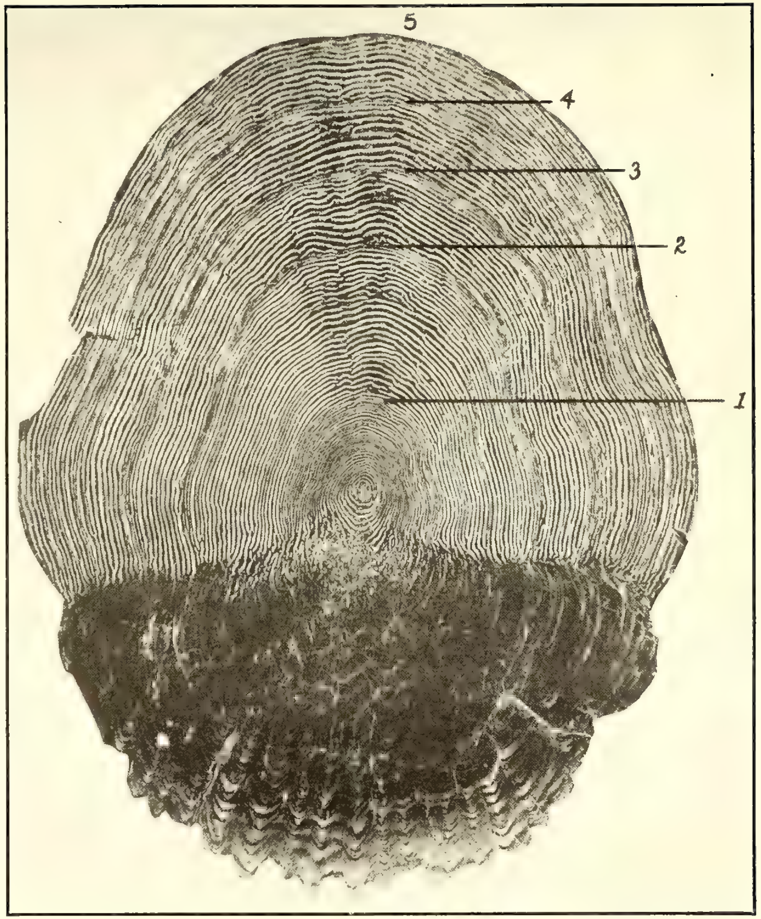

FIG. 32.—Chinook salmon in its fifth year, ocean nucleus, mature. Female, 90.5 cm., log. *D* 0.690. Taken by troll off the mouth of the Columbia River, July 28, 1919. ×20

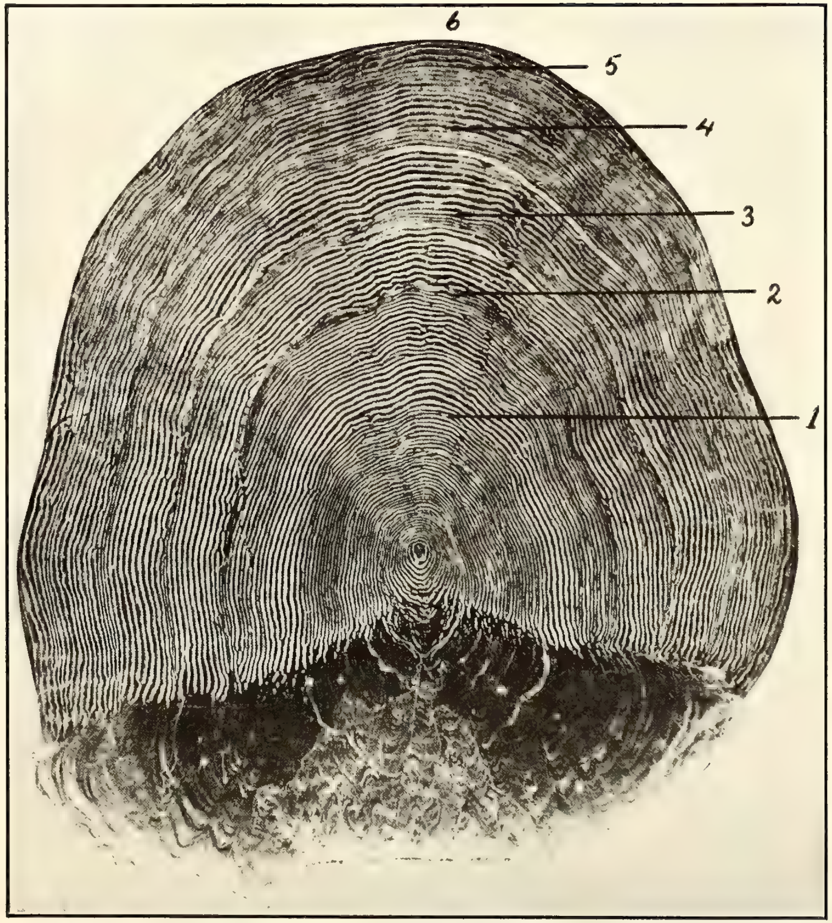

FIG. 33.—Chinook salmon in its sixth year, ocean nucleus, mature. Female, 103 cm., log. *D* 0.681. Taken by troll off the mouth of the Columbia River, July 28, 1919. ×20

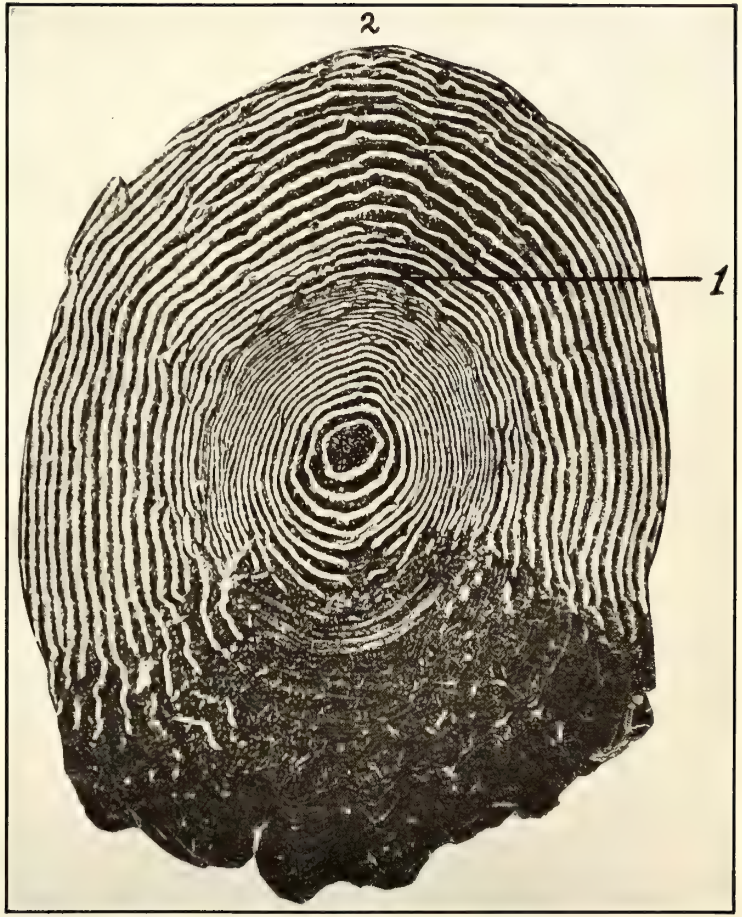

FIG. 34.—Chinook salmon in its second year, stream nucleus, mature. Male, 26 cm. Taken in wheel near Seuferts, Oreg., August 5, 1919. ×35

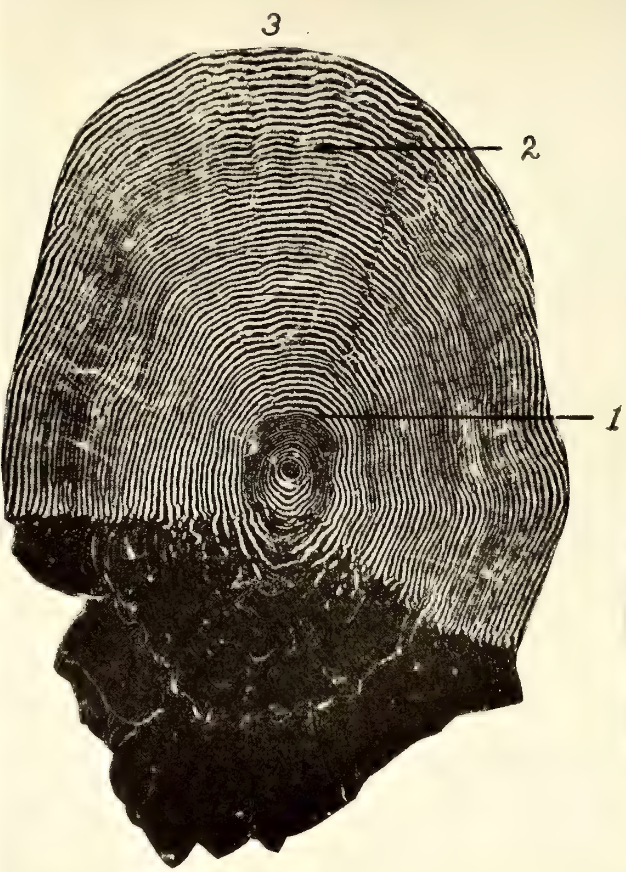

Fig. 35.—Chinook salmon in its third year, stream nucleus, maturity unknown. Male, 50 cm. Taken by troll off the mouth of the Columbia River, June 4, 1919. ×20

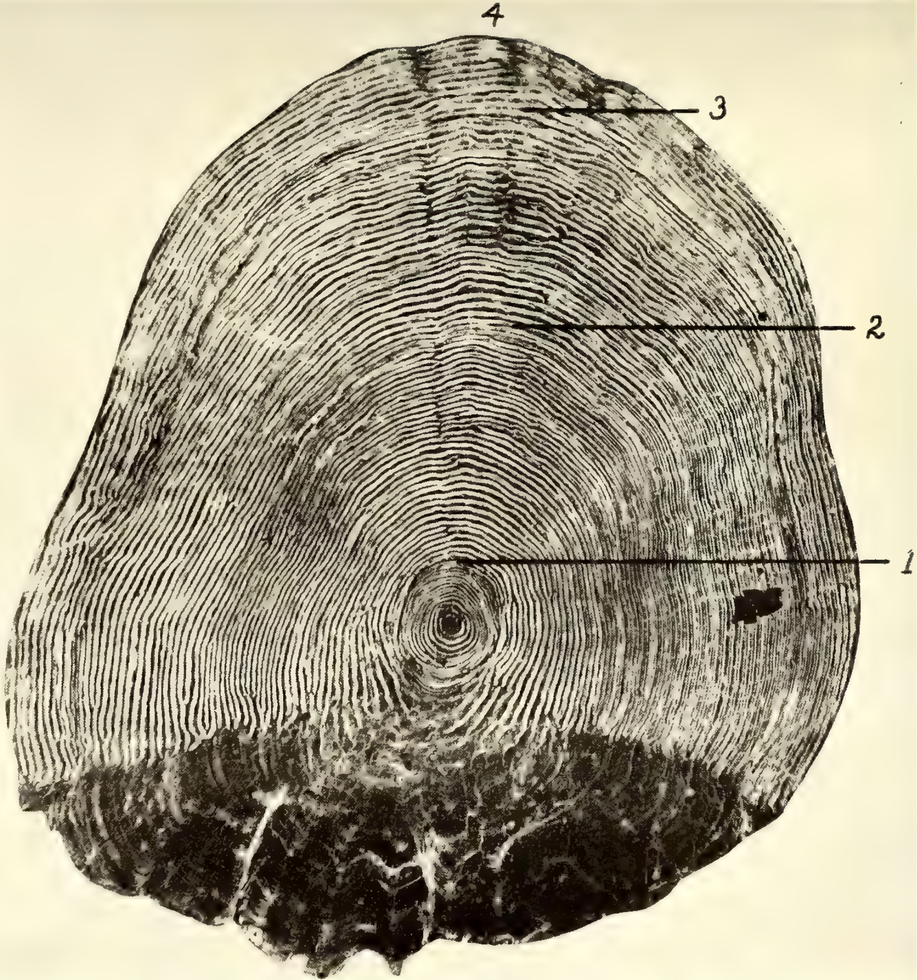

Fig. 36.—Chinook salmon in its fourth year, stream nucleus, immature. Female, 82 cm., log. *D* 0.257. Taken by troll off the mouth of the Columbia River, July 28, 1919. ×20

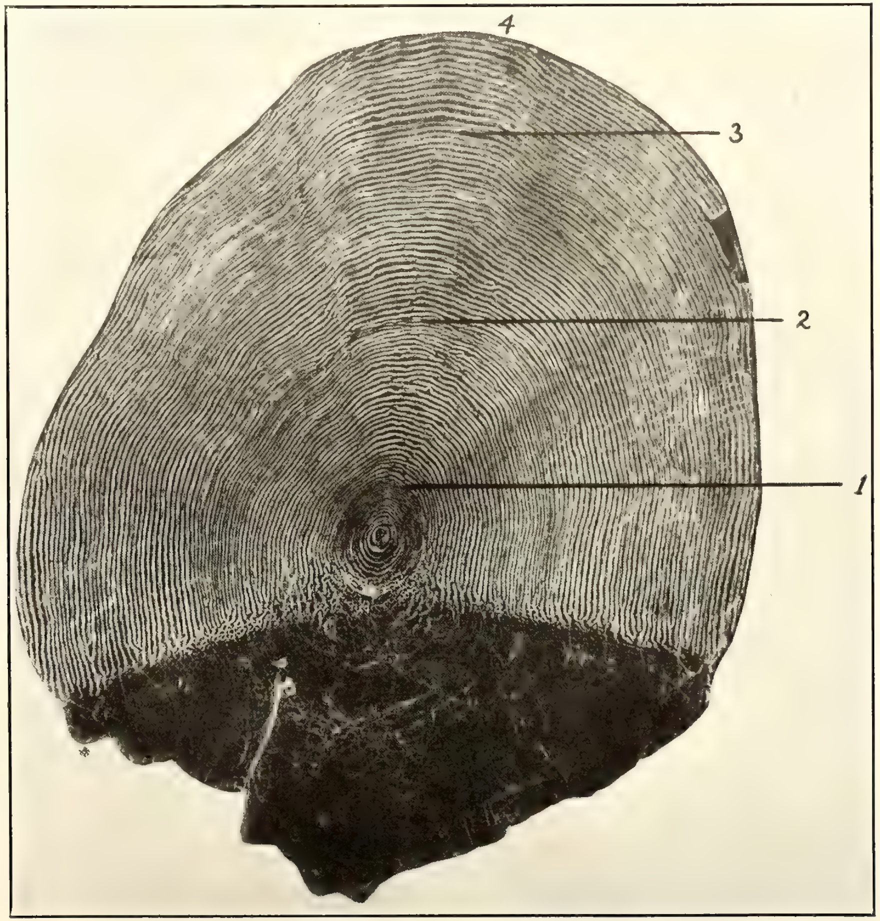

Fig. 37.—Chinook salmon in its fourth year, stream nucleus, mature. Female, 84 cm., log. *D* 0.647. Taken by troll off the mouth of the Columbia River, July 28, 1919. ×20

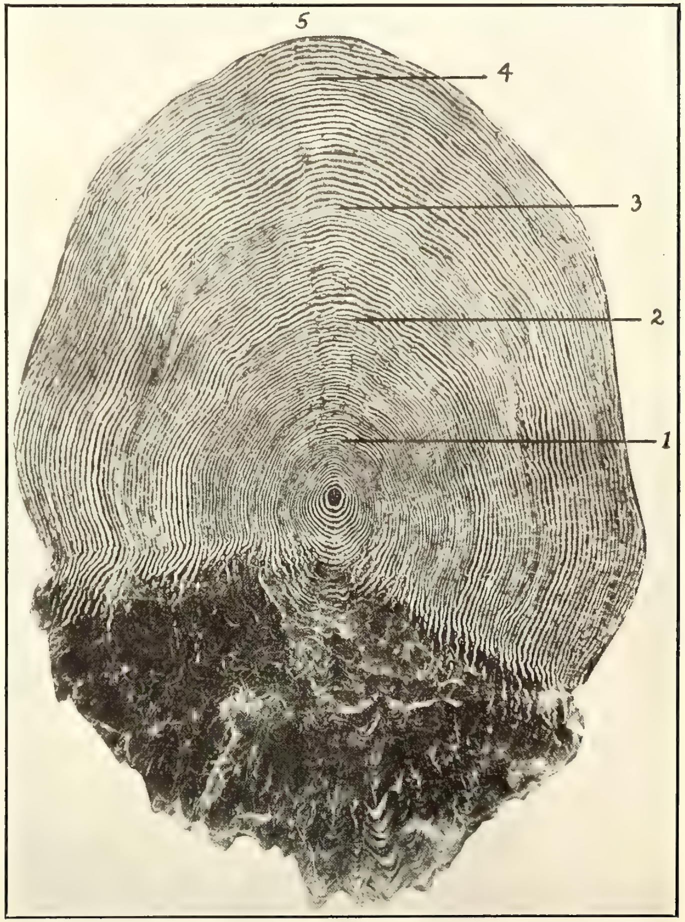

Fig. 38.—Chinook salmon in the fifth year, stream nucleus, immature. Female, 80 cm., log. *D* 0.117. Taken in traps in Baker Bay, Columbia River, May 18, 1920. ×20

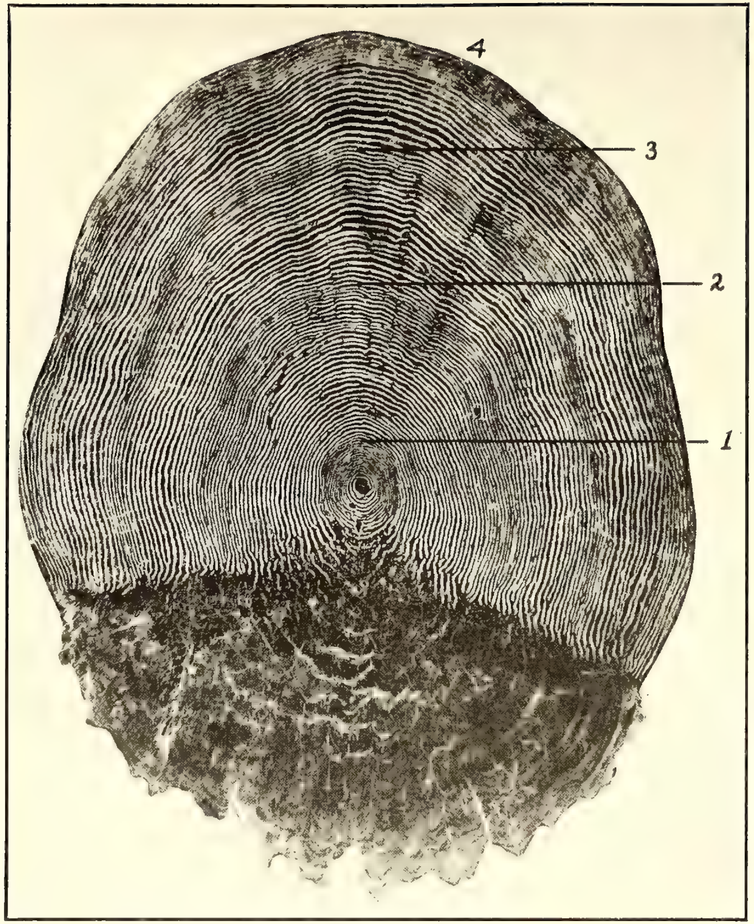

Fig. 39.—Chinook salmon in the fifth year, stream nucleus, mature. Female, 85 cm., log. *D* 0.607. Taken in traps in Baker Bay, Columbia River, May 18, 1920. The new growth of the fifth year had not begun, so that the winter band of the fourth year is at the margin of the scale. ×20

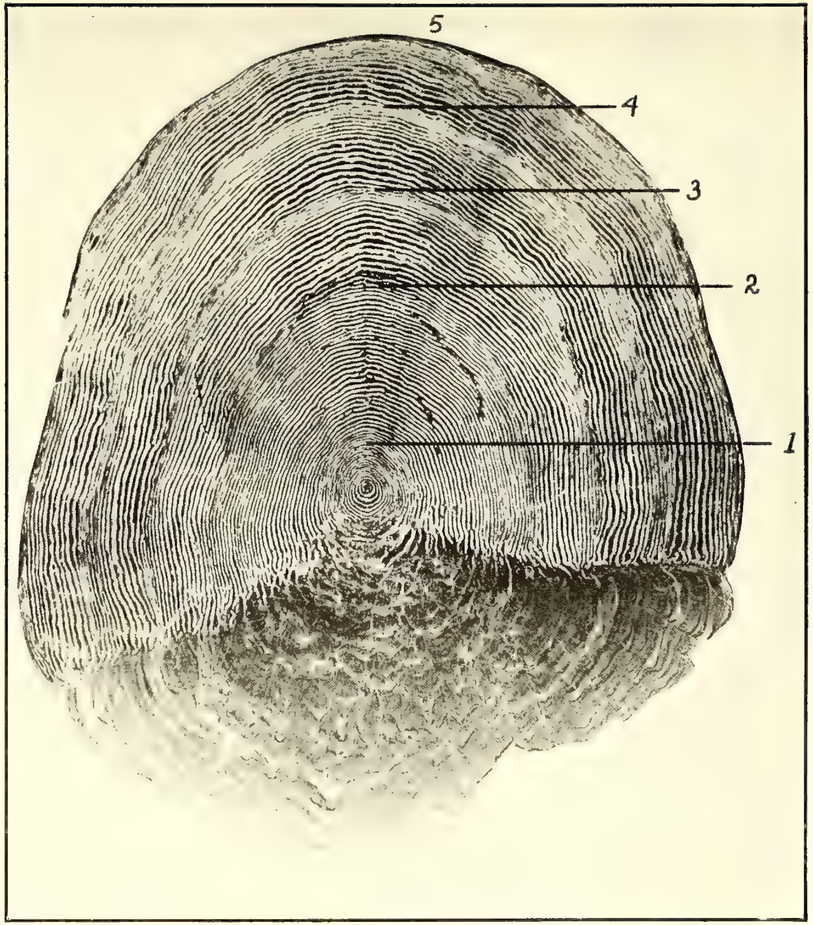

Fig. 40.—Chinook salmon in the sixth year, stream nucleus, mature. Female, 92 cm., log. *D* 0.626. Taken by troll off the mouth of the Columbia River, May 10, 1919. The new growth of the sixth year had not started, so that the marginal rings are those of the fifth winter band. ×20

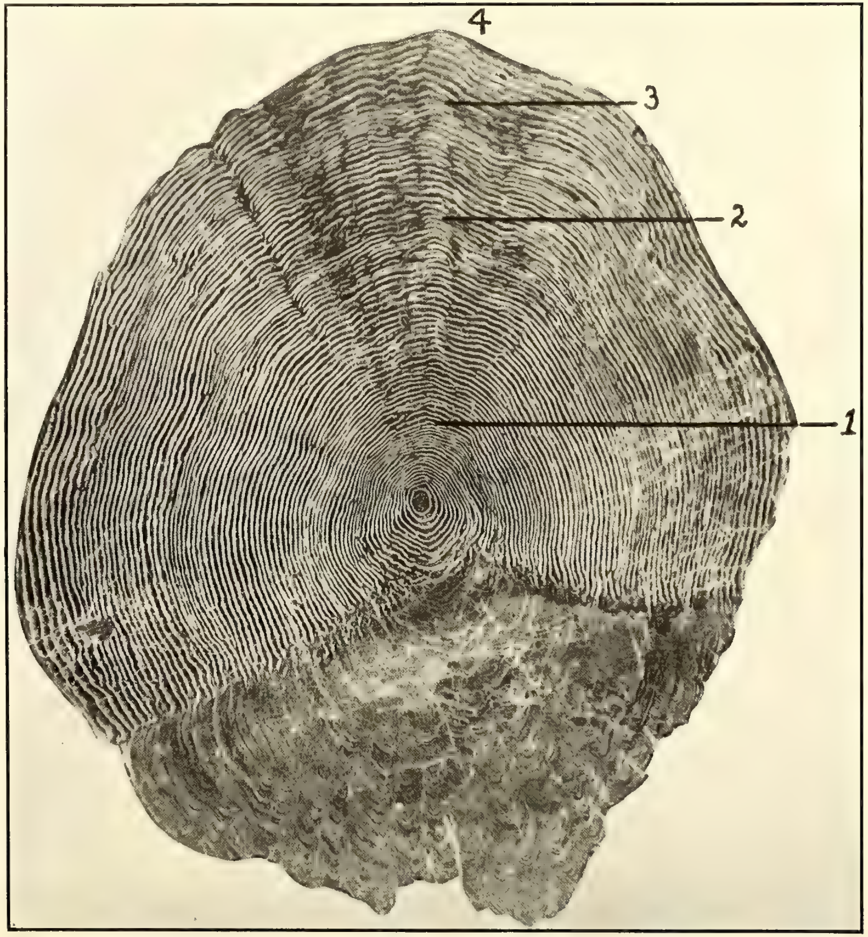

Fig. 41.—Chinook salmon in the fourth year, ocean nucleus. Taken by seine in the Columbia River near Astoria, Oreg., August 22, 1919. This is a representative of the race, having the small type of nucleus, and should be compared with Figure 16. Female, 81 cm. ×20

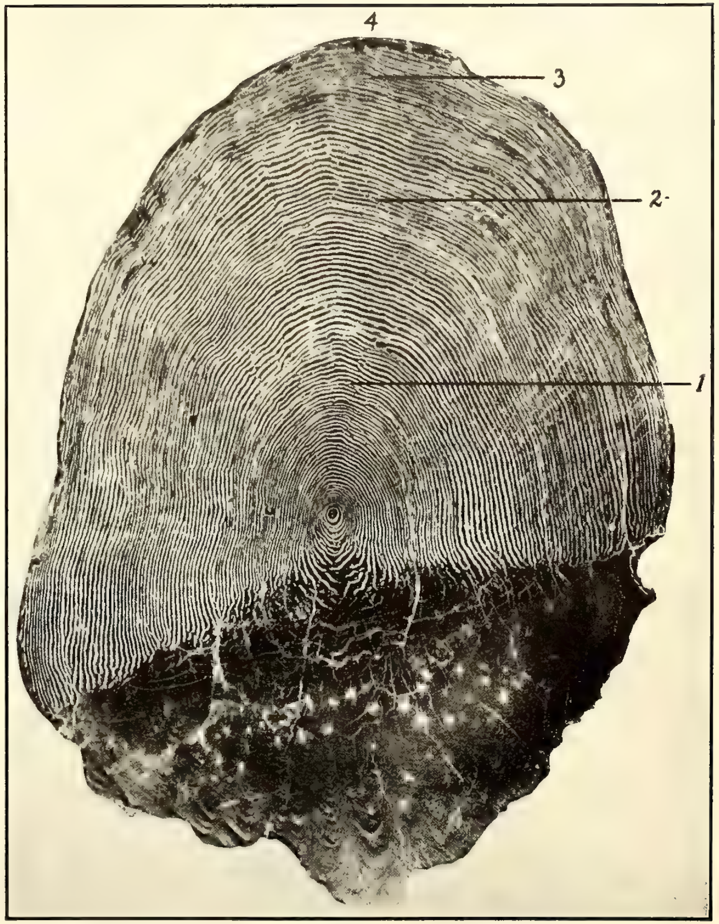

Fig. 42.—Chinook salmon in the fourth year, ocean nucleus. Taken by seine in the Columbia River near Astoria, Oreg., August 22, 1919. This is a representative of the race, having the large type of nucleus, and should be compared with Figure 15. Male, 101.5 cm. ×20

TABLE 22.—*Chinook salmon taken by troll in Monterey Bay, Calif., June 16, 1915*—Continued.

Tabulated according to length, type of nucleus, age, and sex

Centimeter length (mid-value of class)	Ocean nuclei								
	Second year			Third year			Fourth year		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
81				1	1	2			
83					1	1		5	5
85				1		1		5	5
87				1		1	1	3	4
89				1		1		2	2
91							2	1	3
93							1	1	2
95							1		1
97								1	1
99							1		1
Total	23	7	30	17	11	28	7	18	25
Mean	53. 87±0. 54	51. 3	53. 27±0. 46	76. 41±0. 96	75. 54	76. 07±0. 69	90. 48	86. 67±0. 60	87. 72±0. 67
Standard deviation	3. 86± . 38		3. 75± . 33	5. 86± . 68		5. 44± . 49		3. 78± . 43	5. 00± . 48

Centimeter length (mid-value of class)	Ocean nuclei—Continued			Stream nuclei					Total
	Fifth year			Third year	Fourth year			Fifth year	
	Male	Female	Total	Male	Male	Female	Total	Female	
47									2
49									3
51									9
53									4
55									4
57									5
59				1					3
63*									1
67*									1
69									2
71									3
73									7
75									3
77					1		1		4
79						1	1		5
81					1	1	2		4
83									6
85					1	1	2		8
87									5
89		2	2						5
91		2	2						5
93		2	2					2	6
95	1	1	2						3
97		2	2						3
99									1
101	1		1						1
105*	1		1						1
107		1	1						1
109	1		1						1
Total	4	10	14	1	3	3	6	2	106
Mean	102. 5	94. 2	96. 6	59. 0	81. 0	81. 66	81. 33	93. 0	

TABLE 23.—*Eggs from chinook salmon taken by troll in Monterey Bay, Calif., June 29, 1915*

Tabulated according to size of eggs and approximate size of fish

Logarithm of diameter of eggs (mid-value of class)	Group 1[1]	Group 2[2]	Group 3[3]	Total
$\bar{1}.93$	1			1
0.03*	1			1
.07*		1		1
.09	1			1
.15*		2		2
.17		10		10
.19		6		6
.21		7		7
.23		3		3
.25		4		4
.27		4	1	5
.29		4	2	6
.31		7	3	10
.33		6		6
.35		8	1	9
0.37		2	3	5
.39		10	7	17
.41		2	4	6
.43		6	8	14
.45			10	10
.47		1	7	8
.49		1	6	7
.51		2	2	4
.65*			1	1
Total	3	86	55	144
Mean	0.0100	(4)	0.4264±0.0059	
Standard deviation			0.0653± .0042	

[1] Fish under 5 pounds.
[2] Fish between 5 and 15 pounds.
[3] Fish over 15 pounds.
[4] See page 66.

TABLE 24.—*Chinook salmon taken by troll in Monterey Bay, Calif., June 19 to 21, 1918*

Tabulated according to length, type of nucleus, and age

Centimeter length (mid-value of class)	Ocean nuclei			Stream nuclei		Total
	Second year	Third year	Fourth year	Third year	Fourth year	
43	1					1
51*	1					1
57*		1		1		2
59		1				1
63*		2				2
65		2				2
67		9				9
69		4				4
71		5				5
73		2				2
75		8			1	9
77		6				6
79		3				3
81		5			1	6
83		3				3
85					1	1
87			1			1
89			1			1
91			1			1
93			2			2
95			1			1
Total	2	51	6	1	3	63
Mean	47.0	72.64±0.59	91.3	57.0	80.3	
Standard deviation		6.32± .42				

TABLE 25.—*Chinook salmon taken by troll in Monterey Bay, Calif., June 19 to 21, 1918. Females only*

Tabulated according to size of eggs, type of nucleus, and age

Logarithm of diameter of eggs (mid-value of class)	Ocean nuclei			Stream nuclei		Total
	Second year	Third year	Fourth year	Third year	Fourth year	
$\bar{1}.85$	1					1
0.01*	1					1
.07*		1				1
.11*		5				5
.13		3		1		4
.15		6				6
.17		11				11
.19		5				5
.21		3				3
.23		1				1
.25		1				1
.29*					1	1
.33*		3				3
.35		2			1	3
.37		1				1
.39		4	1		1	6
.41		1	1			2
.43		2	1			3
.45		1				1
.47			1			1
.49		1	1			2
.51			1			1
Total	2	51	6	1	3	63
Mean	$\bar{1}.93$	[1]	0.45	0.13	0.343	

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[1] Group with log *D* less than 0.30, mean equals 0.1622±0.0042; standard deviation equals 0.0372±0.0029. Group with log *D* greater than 0.30, mean equals 0.3887±0.0080; standard deviation equals 0.0458±0.0056.

TABLE 26.—*Chinook salmon taken by troll near Drakes Bay and Fort Bragg, Calif., July and August, 1918*

Fish that migrated as fry (scales with ocean nuclei) tabulated according to length, age, and sex

Centimeter length (mid-value of class)	Second year			Third year		
	Male	Female	Total	Male	Female	Total
43	1		1			
45	5	1	6			
47		1	1			
49	1	1	2			
51	1		1			
53	4		4			
61*				2	1	3
63				1	1	2
65				1	1	2
67					3	3
69					2	2
71				1	2	3
73				2		2
75				2		2
79*				3	1	4
81				1	2	3
83				2	2	4
85					2	2
87				1	1	2
89					1	1
91				1		1
Total	12	3	15	17	19	36
Mean	48.33	47.00	48.00	75.23±1.41	74.89±1.37	75.05±0.98
Standard deviation				8.64±1.00	8.84± .97	8.74± .69

Table 26.—*Chinook salmon taken by troll near Drakes Bay and Fort Bragg, Calif., July and August, 1918*—Continued

Centimeter length (mid-value of class)	Fourth year			Fifth year			Total
	Male	Female	Total	Male	Female	Total	
43							1
45							6
47							1
49							2
51							1
53							4
61*							3
63							2
65							2
67							3
69							2
71							3
73							2
75							2
79*		1	1				5
81	1		1				4
83							4
85							2
87		1	1				3
89		1	1				2
91		1	1				2
95*		6	6				6
97	1	5	6				6
99	3	5	8				8
101	4	7	11	1		1	12
103	2	1	3				3
105	4	2	6		1	1	7
107	1		1				1
109	1		1				1
111	3		3				3
113				1		1	1
115				1		1	1
Total	20	30	50	3	1	4	105
Mean	102.70±0.98	97.20±0.65	99.40±0.61	109.60	105.00	108.50	
Standard deviation	6.48± .69	5.30± .46	6.40± .43				

Table 27.—*Chinook salmon taken by troll near Drakes Bay and Fort Bragg, Calif., July and August, 1918*

Logarithm of diameter of eggs (mid-value of class)	Number of individuals		Logarithm of diameter of eggs (mid-value of class)	Number of individuals	
$\bar{1}$.85	1	Mean, $\bar{1}$.8667.	0.43	2	
.87	2		.47*	1	
0.07	1		.51*	4	
.09	1		.55*	3	
.11	2		.57	1	
.13	1	Mean, 0.1778±0.0095.	.59	2	Mean, 0.6244±0.0080.
.15	2	Standard deviation, 0.0600±0.0067.	.61	1	Standard deviation, 0.0780±0.0057.
.17	3		.63	6	
.21*	4		.65	4	
.25*	3		.67	8	
.29*	1		.69	4	
			.71	7	
			Total	64	

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SEASONAL DISTRIBUTION OF THE PLANKTON OF THE WOODS HOLE REGION

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INTRODUCTION

In the plankton section of the report of the Conseil Permanent International pour l'Exploration de la Mer, published in September, 1922, it was pointed out that greater attention should be paid to the seasonal variation and range of marine plankton. As early as 1880, Prof. S. F. Baird remarked to Commander Z. L. Tanner, after the initial cruise of the United States Fish Commission steamer *Fish Hawk*, that "the profitable study of useful sea fishes can not be prosecuted without a knowledge of their food, the food of their food, their respective friends and foes, the habitat of the several species, and their means of passing from one region to another in the embryonic as well as in the adult stage. The temperature, currents, and specific gravity, also, should be studied in connection with the migrations and habits of pelagic forms." Since that time only one area of the Atlantic coast of the United States has been investigated with the object of completely surveying and determining the distribution of the plankton, currents, salinity, and temperature. The interesting results of these investigations, which were carried on by Dr. H. B. Bigelow, are published in a series of bulletins from the Museum of Comparative Zoology at Cambridge, Mass., and a more complete account of these investigations and explorations is now in process of publication.

It has long been known that Woods Hole occupies a unique position on the Atlantic coast. It is the northern limit of many southern forms and the southern limit of many northern forms. Oceanic animals, also, are often carried into this pocket on the coast by the southerly winds and strong tides that prevail in the summer months. For that reason Woods Hole was selected as an ideal location for the study of plankton and the interrelationships of the various pelagic faunas.

Under "plankton" I have included all animals occurring in surface collections, whether free-swimming or carried by currents. Such a broad definition includes a great many benthonic forms carried from their natural habitat by storms or high winds, but in a littoral region one can not always decide accurately which species have been accidentally carried to the surface and which are free-swimming.

The present paper is the result of a continuous investigation of the plankton in Great Harbor, Woods Hole, Mass., covering a period of two years. The purpose was to make an exhaustive qualitative study of the plankton of this region, the seasonal distribution of the various species, their interrelationships, and the general factors governing their distribution.

The investigation consisted of three parts: (1) An examination of plankton samples taken daily during the years 1899 and 1900 in Great Harbor by the late Vinal N. Edwards, collector for the United States Fish Commission; (2) a survey of all records of surface collections of previous years; and (3) examination of living material taken daily in surface collections in Great Harbor, observations on temperature, salinity, and other factors governing the seasonal distribution of the plankton, and a survey of the general geography of the region as a factor affecting plankton distribution.

The first part of the investigation occupied the entire time of the author during the year 1921–22 and was carried on in the biological laboratory at Brown University. Many of the fragile animals had become disintegrated during the 22 years in which the material had remained untouched, and the preservatives in some of the samples had evaporated. Over 200 vials remained intact, however, and offered ample material for study.

The second part of the work involved much time and proved to be a very tedious task. The results, however, were very important, as they covered the daily records of surface collections extending over a period of 15 years—1893 to 1907, inclusive. The larval fish and cœlenterates taken during this time had been carefully identified by Vinal N. Edwards. Diatoms, copepods, amphipods, annelids, and other planktonic forms were recorded as groups, the relative abundance for each day being carefully noted. Complete records of the weather, wind, and temperature for most of this period were available and proved indispensable in explaining peculiarities in the seasonal distribution of many species. This part of the work was done by Marie D. P. Fish, who aided me in the study of the larval fish also.

The final part of the work was carried on from June 22, 1922, until December 31, 1923, at the laboratory of the United States Bureau of Fisheries at Woods Hole, Mass. From June 22, 1922, until May 1, 1923, observations were made daily at the same spot where all my previous material had been taken. Fortunately a series of collections had been made by R. A. Goffin during the spring of 1922. From these I was able to trace the first appearance of the summer species. From May 1 to December 1, 1923, the collections were made three times a week, except during the interval from August 22 to October 4. The records for the past summer are therefore not as complete as those of 1922, although they serve as a basis for comparison.

A kind invitation from Dr. P. S. Galtsoff to assist him in his monthly surveys of Long Island Sound from September, 1922, to August, 1923, made possible valuable observations on the distribution of certain pelagic organisms, particularly the diatoms, in relation to their presence at Woods Hole.

It is a pleasure to express my especial gratitude to Prof. A. D. Mead and Prof. R. M. Field, of Brown University, who furnished me helpful assistance and guidance throughout my work. I am especially indebted to Marie D. P. Fish for her careful tabulation of Vinal N. Edwards's records of surface collections and temperatures collected over a period of 15 years. I am indebted to Dr. P. S. Galtsoff, who made possible my observations on salinity at Woods Hole and the plankton of adjacent regions, and I wish also to express thanks to Dr. Henry B. Bigelow, Dr. Hugh M. Smith, Dr. Paul Bartsch, Dr. Albert Mann, and Prof. A. E. Verrill, for helpful advice and criticism rendered at various times during the progress of my work.

METHODS

My first plans provided for daily observations on temperature of the air and water (surface and bottom), salinity, oxygen, wind, weather, sea, transparency, vertical hauls, and surface and bottom collections with plankton nets of No. 2 and No. 20 bolting cloth. Because of the amount of time required to identify the many species of zooplankton and phytoplankton it was found desirable to discontinue certain of these observations. The following schedule was finally adopted:

1. Daily temperatures of surface water and air.
2. Salinity (at certain periods) and density.
3. Daily meteorologic observations on wind, weather, sea, etc.
4. Vertical hauls at weekly intervals with No. 20 net.
5. Daily surface hauls with No. 2 and No. 20 nets. (Later, No. 20-net hauls were reduced to twice a week except during the diatom maxima.) Nets 3 feet by 12 inches with a brass bayonet-lock bucket on bottom were used.

The temperature was taken each day at the time of setting the plankton nets. A series of observations later proved conclusively that at all times the bottom temperature at my station is exactly the same as that of the surface (Table 2, p. 101). Bottom observations then were made only during periods of rapidly declining or rising temperatures.

For a period extending over four months salinity was determined daily by titration with nitrate of silver. When these could not be made at once, they were preserved in the standard "citrate of magnesia" bottles of the sort used for that purpose by the United States Bureau of Fisheries. After it was found that there were usually no important variations observations were made only on certain occasions to indicate the influx of Gulf Stream and other ocean water. Had it been possible continuation of the daily tests would have been very desirable.

Observations on the condition of the weather, sea, wind, and sky were taken daily. These factors are of great importance, particularly the winds, in determining the distribution of planktonic animals.

Vertical hauls were made weekly, but they yielded rather disappointing results. The water is only 11 feet deep at low tide, and for that reason a very small net of the Birge type, with a special bucket, was adopted. The material collected was centrifuged for two minutes at about 1,000 revolutions per minute in a graduated glass tube, and the result measured in cubic centimeters. The figures obtained are not included in this report because I did not have time to make individual counts of the various species, and the total mass was meaningless, being made up of diatoms, dinoflagellates, particles of dirt and detritus, larval copepods, larval mollusks, and an occasional adult copepod. All the large planktonic forms had successfully evaded the net as it was being drawn to the surface, and the resulting mass did not give a fair estimate of the amount of plankton in the water at the time. To get these various-sized animals, a series of nets of at least 10 different meshes would be necessary, and even with these there would be so much overlapping that the results would be of little value. The pump has not succeeded in overcoming this difficulty in the case of the marine plankton. On eight occasions during the past year I centrifuged over 100 samples taken by pump in Long Island Sound, and invariably the deposit contained a larger proportion of small forms and a smaller proportion of large forms than did the vertical hauls made at the same time. A successful method of accurately determining the real volume of marine zooplankton as well as of phytoplankton is yet to be devised.

The most valuable results were obtained with surface nets. The waters are so churned up in Great Harbor that there was no difference in the collections taken at the surface and those taken at the bottom, except that the latter often contained more sand and small detritus. For that reason the bottom hauls were discontinued.

The daily routine of plankton collecting and investigation, consisted of three parts. First, the nets were suspended from the end of the dock by means of pulleys attached to outlying piles in such a position that one was suspended in a northerly direction and the other in a southerly one (fig. 1, p. 97).

When the nets were hauled the contents were emptied into a flat glass dish entirely covered with black paint except for a small area at one corner. A tight-fitting top completely shut out all light except in the corner over the clear glass. A light placed at this end caused all the Crustacea, larval annelids, and, in fact, most of the free-swimming planktonic organisms that are positively phototropic to crowd at the lighted corner, where they could be picked out individually with a pipette or drawn out in bunches with a long glass tube and deposited in a watch glass or petri dish for examination. A second collection was then made from the detritus in the bottom, consisting of dead organisms and any forms that had not been attracted to the light. Finally, the last bit of sediment, after all the rest of the tow had been poured into a silk bag to be strained, was placed in a dish. This was often found to contain large numbers of small mollusks, ostracods, and Foraminifera.

After the living specimens had been observed they were killed with a 2 per cent solution of formalin and reexamined. The species not readily identified were placed in separate watch glasses and subjected later to a more careful examination with a higher-power lens. For a general examination of zooplankton a binocular microscope with low-power lenses (Nos. 55, 40, and 24) is very satisfactory. Smaller forms were mounted on slides and examined with a compound microscope.

Several samples of phytoplankton were placed in watch glasses and examined alive. This made possible a rapid survey of a large amount of material. Next some of the material was mounted on slides, with barium mercuric iodide as a mounting medium, and examined with a higher-power lens.

The common species were tabulated daily on charts, records being made of the rarer specimens. If these began to appear frequently, they were given a place on the chart. This method proved to be very simple and convenient. The material was later put in 2 per cent formalin and labeled for future reference.

The direction of the currents in Great Harbor during the flood tide (fig. 1, p. 97) was determined in two ways. The first method was very simple, consisting of observations made while great masses of broken ice were floating through the passage during the spring months. The results obtained in this way could be checked up as often as desired. The second method was used to determine the smaller currents near shore, and the course of the back eddy along the shore of Nonamesset. This was accomplished by placing large quantities of shavings in the water on a calm day and plotting the courses which they took. The results may not be entirely accurate in minute details, but they show the general movements of the water in the harbor during flood tide.

The combined results of my observations on material of 1899-1900 and those of Mr. Edwards have been plotted on quadrille paper. The charts based on the work of the past two years are on Keuffel and Esser No. 334D graph paper.

A great difficulty presented itself when I started to assemble my results. In qualitative work the greatest amount of material possible is essential, and the only way to obtain this is by surface towing, which obviously does not lend itself to any accurate measurement. Even if figures could be secured the daily variation in the winds and tides is so great at Woods Hole that the results would be more confusing than helpful. One can state when the first specimen of a species appears and when its season ends, and the fact that the numbers may be increasing daily can also be seen, but to present this information in a satisfactory manner is difficult.

The plan finally adopted consisted of the use of four categories—very scarce, scarce, abundant, and very abundant. These served as calibrating points from which the seasonal distribution of a species could be plotted in a fairly accurate manner. Of course, the basis for measuring the abundance of copepods was not the same as that for the diatoms; 500 of the former might be considered abundant, while the same number of diatoms would be considered very scanty. Again, 50 specimens of the oceanic annelid, Tomopterus, would be considered abundant, but 50 specimens of a common copepod would be thought scarce. The measurement, therefore, is relative; that is, *the symbol given to a particular animal for a* *particular day indicates its relative abundance for that day compared with its abundance for all the preceding days or weeks since its appearance and is not to be compared with that of the species of any other phylum.* To eliminate as far as possible the confusion arising from daily variation, three-day averages were used in plotting the points on the charts. There may be objections to my method of presenting the data in graphic form where definite figures were not available. However, I feel that the seasonal variation can best be shown in this way, and that any method which simplifies the work and makes it more easily understood is justifiable. The symbols used on the charts are as follows: *V. A.*, very abundant; *A.*, abundant; *S.*, scarce; *V. S.*, very scarce; and *N.*, none.

LOCATION

All material for the present investigation, with the exception of a few observations made in Vineyard Sound, was obtained from the water at the end of the Bureau of Fisheries dock at Woods Hole, Mass. This spot was selected, first, because it offered such excellent possibilities for qualitative plankton investigation, and, second, because the bottom fauna, whose larvæ make up a large percentage of the summer plankton, had already been carefully surveyed.

The location is an exceptionally fortunate one for an investigation of seasonal distribution, although impossible for a study of diurnal migration. On the flood tide the local current rushing through the narrow passage of Woods Hole sometimes reaches a speed of 8 miles an hour. Figure 1 shows that one of the three main branches of this current heads directly for the Fisheries dock. Here it divides, one half turning to the south and the other to the north. By placing nets at the two ends of the dock one hour after the tide has turned to flood and hauling them one hour before the ebb it is possible to have a strong current of water passing through the nets continuously for four hours. More material can be collected in this way than would be possible in several hours' towing from a boat. To determine the complete pelagic fauna of a region, the largest possible number of daily samples are needed. Even then many scarce forms probably pass through their seasonal cycle without once being observed in surface collections.

Another advantage of the position of this particular station is the uniformity of the plankton both during the day and during the night. Extended observations showed that the mixture of the waters during the flood tide so churns up the plankton that there is almost no difference between the hauls of the day and those taken in the evening. I know of but two exceptions to this statement. These are the amphipods and certain annelids, which remain under rocks in the daylight and emerge after dark. Then they are picked up by the strong currents and appear in the greatest numbers in evening collections. As these are not true pelagic animals, they do not seriously affect the problem. Thus, the collections made at any time showed equally well the representative plankton for that day.

The features of the coast adjacent to Woods Hole have much to do with its fauna. It has long been thought that the arm of Cape Cod to the east constitutes a barrier that changes the course of the cold northern ocean current and deflects it away from the continent. Not all oceanographers agree as to the above, but even

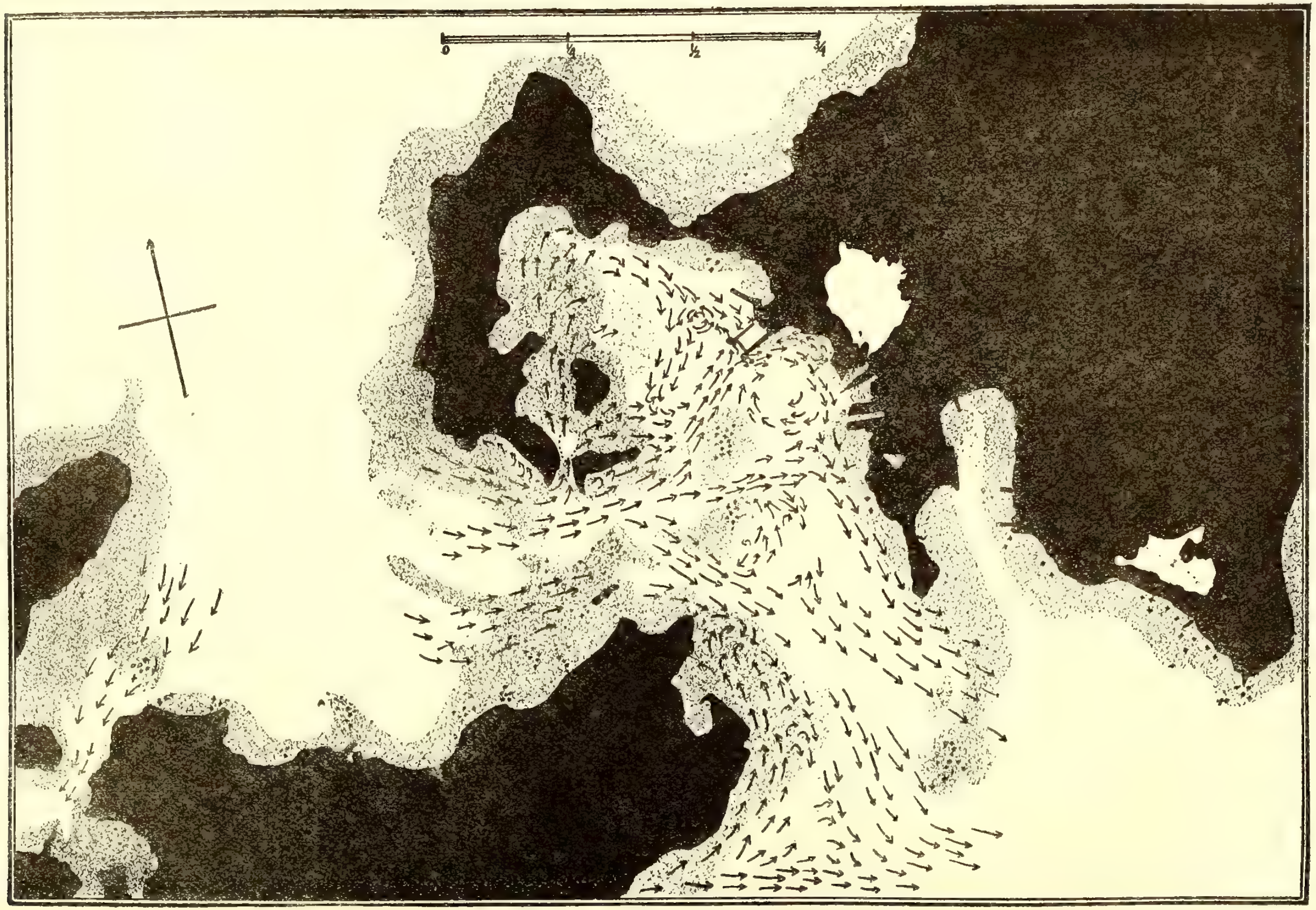


Fig. 1.—Currents of Great Harbor, Woods Hole, Mass., during flood tide. Light shaded area, shallow water; black area, land; +, rocks; ●, location of plankton nets. Scale in statute miles

if this is not true, Verrill and subsequent authors, including Bigelow (1914–1922), found that the coastal water temperatures north and east of Cape Cod were very much lower in summer than those south of it. None of the planktonic animals common north of the cape appear south of it in summer. In winter, however, the cape does not form a barrier for the neritic plankton, which often appears at Woods Hole in great abundance.

The Gulf Stream lies about 85 nautical miles off the Massachusetts coast, just beyond the end of the Continental Shelf. Between this warm area and the mainland there is a broad belt extending from the north. Some consider this to be a continuation of the Labrador current and attempt to explain faunal distribution on that basis. Others consider it to be mainly a contrast belt between the warm littoral zone and the Gulf Stream. According to the latter viewpoint, the Labrador current does not extend south of Newfoundland. No matter which theory is correct it is evident that this broad belt is affected on one side by the southerly winds and on the other by the unusually strong tides of this region. Any forms, then, that have blown in from the Gulf Stream will be carried farther inland by the moving water. This peculiar alliance of wind and tide probably explains why much tropical plankton, which is taken so often in this locality, occurs at no other points along the coast.

Woods Hole also forms the northern limit of most of the southern boreal pelagic animals. Many copepods and cœlenterates, of which Mnemeopsis is a striking example, occur often in Great Harbor but never farther north along the coast. Thus, it is clearly evident that Woods Hole is a very unsatisfactory spot to work out the characteristic pelagic fauna of the north Atlantic coast region, for not only northern and southern boreal types appear with the littoral plankton at certain seasons, but the Gulf Stream and other oceanic forms are likely to be carried in at any time. Again, the swift currents rushing through the passage produce local peculiarities in the plankton. However, if we desire to study the conditions at Woods Hole as a special problem and try to understand the conglomeration of faunas, their interrelations, and the factors governing their appearance and disappearance it becomes highly interesting and instructive.

SALINITY AND DENSITY

The salinity at Woods Hole normally varies comparatively little throughout the year. No streams of importance empty into Great Harbor, and as all the larger rivers of Buzzards Bay are situated at the upper end the salinity of the southern area is not sufficiently different from that of the sound to have any appreciable effect on the plankton.

Titrations made almost daily from July until October, 1922, during the flood tide (Table 1) indicate that the water entering Great Harbor is of a slightly lower salinity than that of Vineyard Sound, found by Bigelow (1915) to be 32.2 per mille in August, 1913, and by Sumner (1913) to be 32.2 per mille in August, 1906. In 1922 the average salinity at the Fisheries dock for late July and August was 31.57 per mille, and for September and early October, 31.03 per mille.

TABLE 1.—*Salinity of surface water at Woods Hole from July to October, 1922*

Date	Degree of salinity	Date	Degree of salinity	Date	Degree of salinity	Date	Degree of salinity	Date	Degree of salinity	Date	Degree of salinity
July 27	31.53	Aug. 6	30.30	Aug. 16	31.58	Aug. 27	31.85	Sept. 8	31.22	Sept. 24	31.40
July 28	31.46	Aug. 7	31.20	Aug. 17	31.53	Aug. 28	31.31	Sept. 9	31.18	Sept. 27	31.44
July 29	31.62	Aug. 8	31.29	Aug. 18	31.82	Aug. 29	31.49	Sept. 10	31.33	Sept. 29	31.40
July 30	31.31	Aug. 9	32.01	Aug. 19	31.60	Sept. 1	31.36	Sept. 11	31.02	Sept. 30	31.62
July 31	31.31	Aug. 10	32.01	Aug. 20	31.65	Sept. 2	31.36	Sept. 12	31.06	Oct. 1	30.88
Aug. 1	31.31	Aug. 11	31.73	Aug. 21	31.85	Sept. 3	31.09	Sept. 13	31.15	Oct. 2	31.35
Aug. 2	31.56	Aug. 12	31.82	Aug. 22	31.85	Sept. 4	30.91	Sept. 14	31.18	Oct. 5	31.35
Aug. 3	31.71	Aug. 13	31.53	Aug. 23	31.85	Sept. 5	31.18	Sept. 16	31.15	Oct. 10	31.49
Aug. 4	31.64	Aug. 14	31.60	Aug. 24	31.65	Sept. 6	31.04	Sept. 17	31.06	Oct. 11	31.20
Aug. 5	31.46	Aug. 15	31.67	Aug. 25	31.71	Sept. 7	31.49				

After southerly winds a slight increase in salinity usually can be noted. This would naturally be expected, for the outlying waters always have a higher salinity—in the case of the Gulf Stream upwards of 35 per mille. It was to determine to what extent this influx of ocean waters takes place after storms that the titrations were made in Great Harbor. They covered the period when most tropical oceanic animals appear in the plankton. The results showed that very little change takes place even during hard southerly winds unless they extend over a long period of time. This is probably due to a dilution resulting from a mixture with the fresher waters of the southern part of the bay. Marked changes may have occurred in Vineyard Sound but were not evident farther inland.

On August 6 and 7 a heavy southwest storm took place, reaching its height on the second day. During this time the wind blew continuously and much Sargassum was noticed in the sound. A slight increase in salinity from 31.29 to 32.01 per mille on August 9 and 10, followed by a gradual decline, was the only evidence of outside water, and this was below the usual average for the Sound in August. However, this again may have represented a mixing of the bay water with that of a higher salinity than is usually found in the sound.

Hard southerly winds extending over a long period of time replace the waters of the region to such an extent that the dilution by bay water is hardly noticeable except after a hard rain or a period of melting snow. This was shown by the density records during the spring of 1922. Figures 2 and 3 give the daily variation in the density at Great Harbor, taken by Mr. Hamblin at the Fisheries dock at 12 o'clock noon. As these unfortunately have no relation to the tides, they can only indicate in a general way the conditions existing at any particular time. Standard hydrometers, certified by the Bureau of Standards, were used, the error being probably not greater than ± 0.0001.

The density in shallow waters is governed by two factors, temperature and salinity, the comparative influence of each being clearly shown in Figures 2 and 3. A comparison of Figures 2 and 3 with Figures 4 and 5 indicates the effect of the temperature. During the warmest seasons a minimum density is found, and during the coldest months it reaches its highest point. Were there no change in the salinity the curve would rise and fall evenly, corresponding to the rise and fall in the temperature of the water. The sudden increase or decrease in the curve at any particular time is due to an increase or decrease in salinity. As previously stated, there are no rivers in the immediate vicinity of Great Harbor, although melting snow and hard northerly winds cause the sudden appearance of waters of comparatively low density. Prevailing southerly winds extending over a long period of time cause high density. In the spring of 1922 (fig. 2), combined with the usual low temperature, the density almost equaled that of ocean water and remained that way until the middle of May.

The effect of melting snow shows clearly (fig. 2) in the first week of April, 1922, and (fig. 3) on January 2 and 3, 1923. On the latter dates a marked increase in the number of diatoms was also noticeable. The greatest change took place on March 31, when the density dropped from 1.0260 to 1.0244 in one day. A heavy snowstorm had occurred on March 30, followed by rain and snow on March 31 and April 1. The rapid rise took place during a period of constant hard southwesterly winds. The extreme point reached on April 9 (1.0270), accompanied by a drop of 1° in temperature, is impossible to explain on the basis of local conditions. Southerly winds prevailed, but were not unusually strong. Some hydrographical change beyond the limits of the immediate region must have accounted for it.

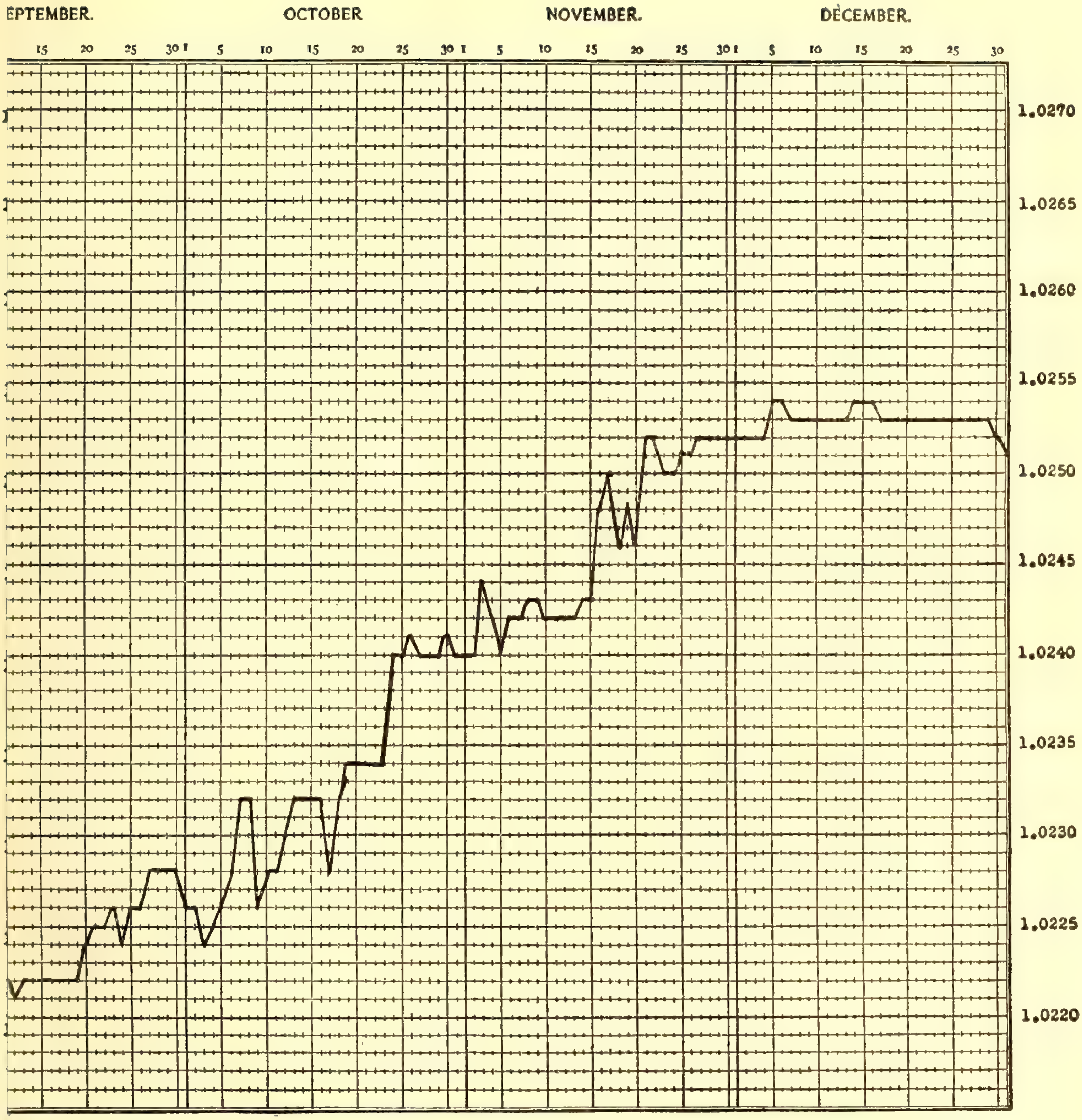
It is probable that the salinity plays little or no part in the seasonal distribution of the planktonic animals of this region. The fresh waters of the upper bay no doubt form a barrier for the oceanic species and the brackish water forms probably do not go far out to sea. Such conditions, however, are not found in this immediate region.

TEMPERATURE

The subject of the temperature at Woods Hole and adjacent regions is so fully discussed by Sumner in his report that only the particular conditions existing in Great Harbor during the past two years need be considered here.

Figures 4 and 5 show the variations in the temperature of the air and water for the years 1922–23, inclusive, to December 31. The figures were obtained from the records taken daily at 8 a. m. by Mr. Hamblin, of the Bureau of Fisheries. This hour was selected because it eliminates the temporary midday rise of surface temperature typical of all shallow water. Figure 6 was compiled by Sumner to show the mean average temperature of the air and water for a period of five years. A comparison of this chart with that of the past year shows many important points. The fact that Sumner's chart is based on noon records must be considered, although it probably had little effect on the water curve. The highest point on this curve is on August 12, when the mean temperature was slightly over 71° F. The highest point reached in 1922 was 71° F., on August 8. The curve for 1922 agrees well with that of the average temperature for other years. The lower point of the latter (30° F.) was reached only once, on February 19. In 1922 the curve fell below this on two occasions (January 25 and February 17–19), and reached it on February 4.

During the spring of 1923 very unusual conditions prevailed. The temperature went below 30° F. on January 29, and never rose above this point until March 14. Throughout this period the temperatures fluctuated between 28.5 and 29° F., reaching 28° F. on February 24. This unusually cold water, occurring for such an extended period, accounts for certain peculiarities in the plankton of the present



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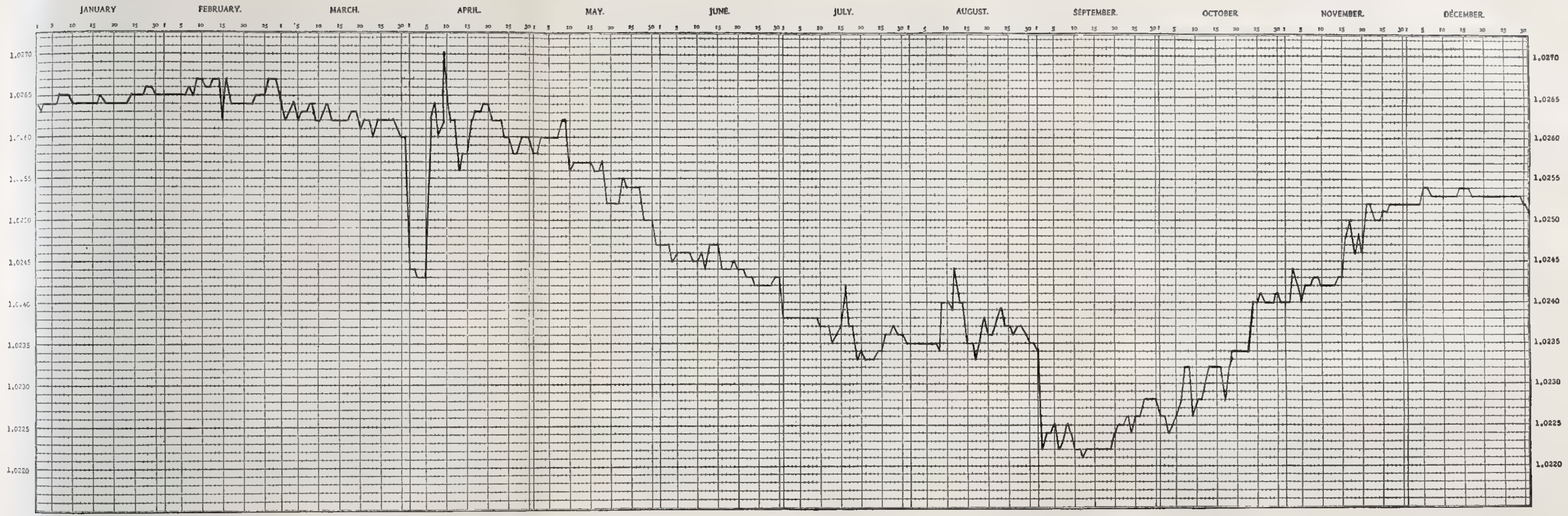

FIG. 2.—Diagram showing density of water at Woods Hole, Mass., for each day of the year 1922. Observations made at 12 o'clock noon. Density at the temperature in situ

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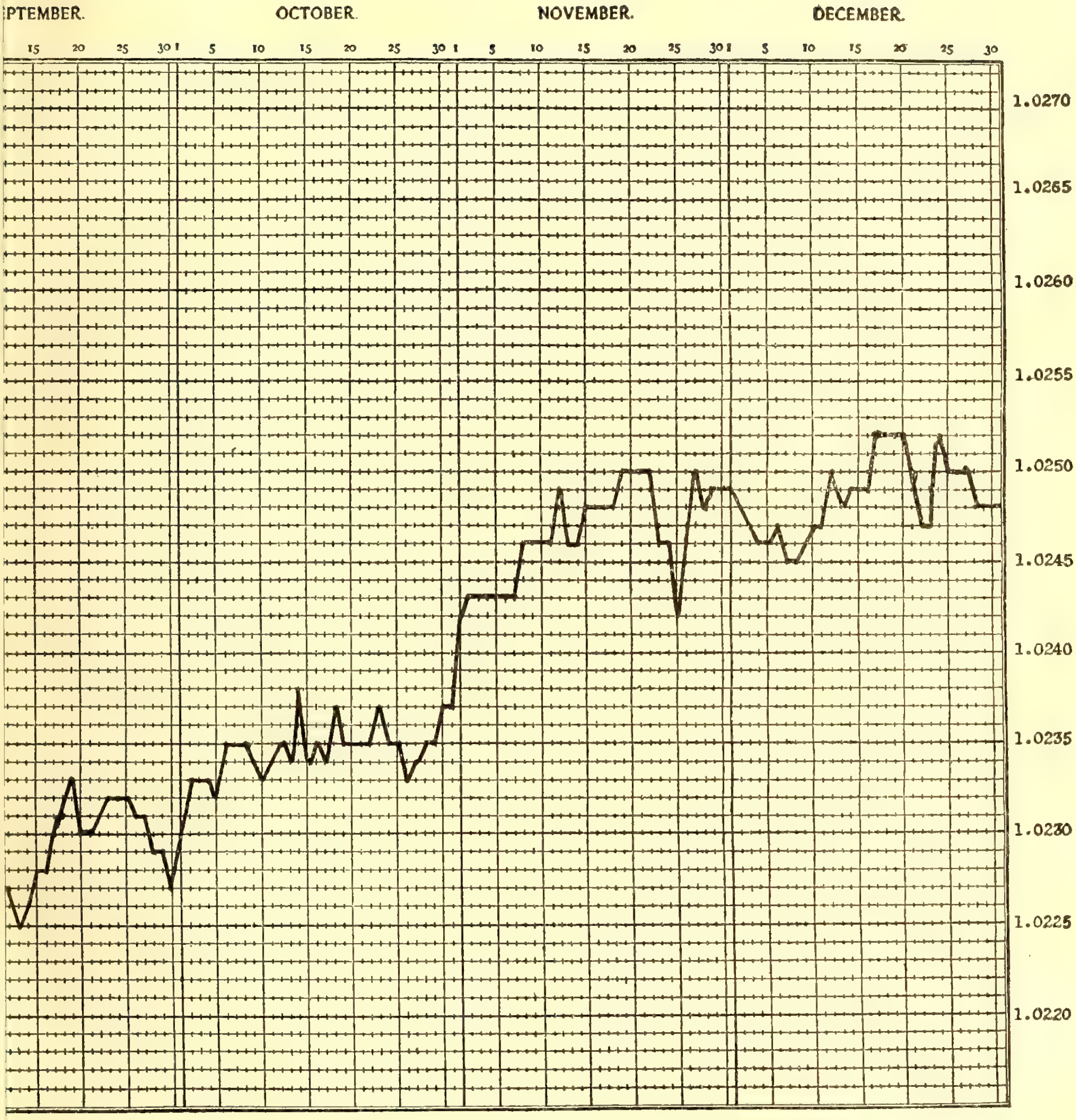
PTEMBER.
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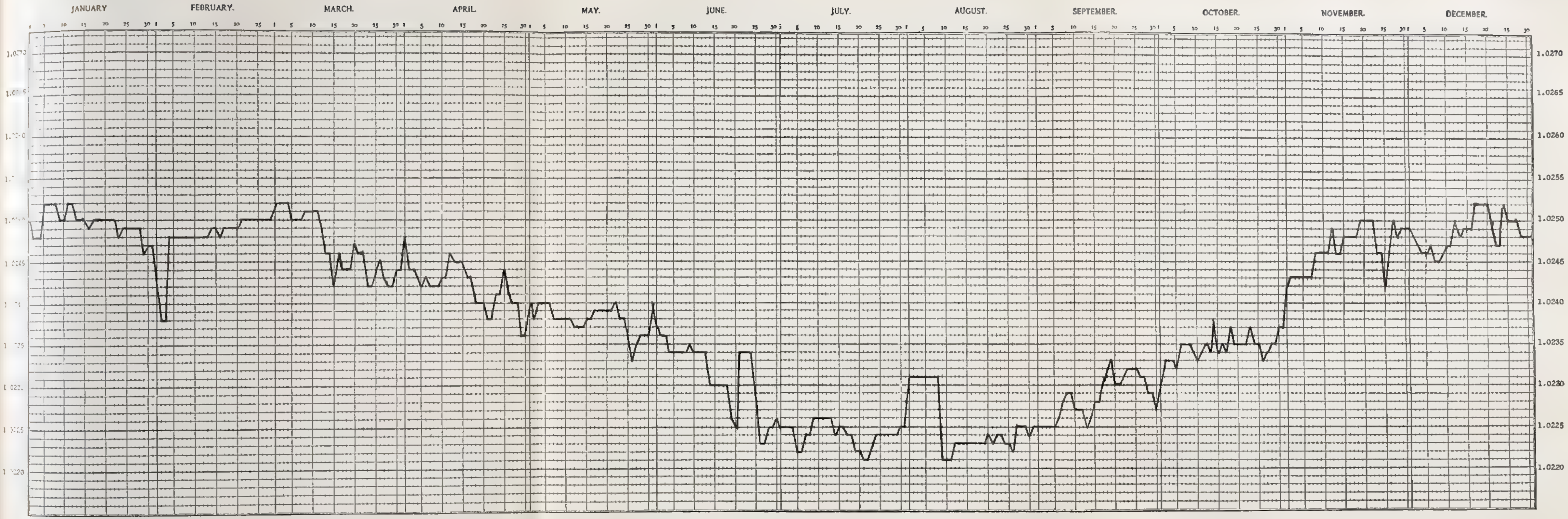

FIG. 3.—Diagram showing density of the water at Woods Hole, Mass., for each day of the year 1923. Observations made at 12 o'clock noon. Density at the temperature in situ

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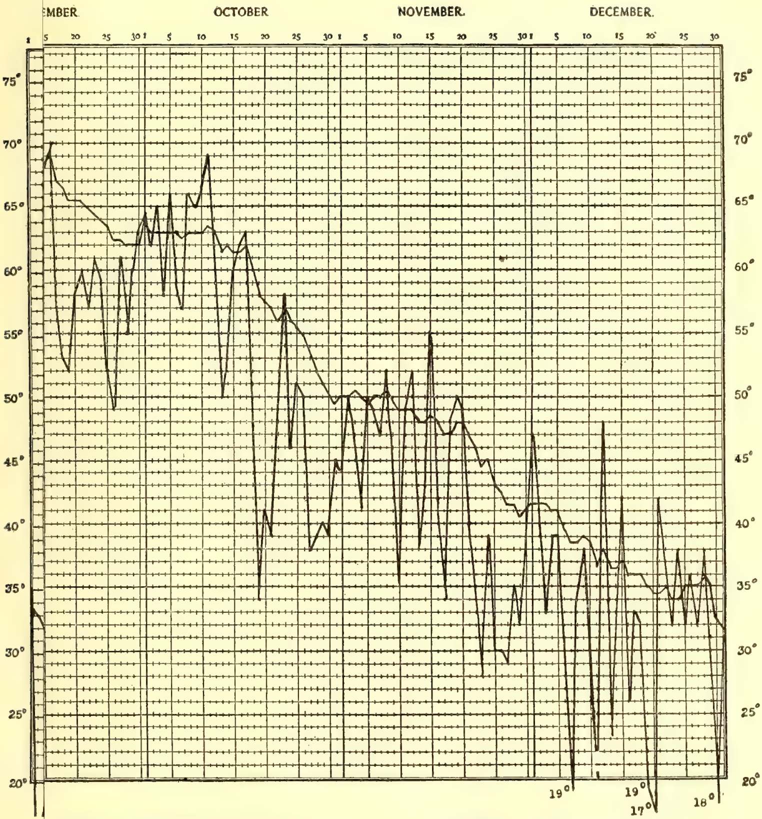

Fahrenheit, and observations were made at 8 a. m.

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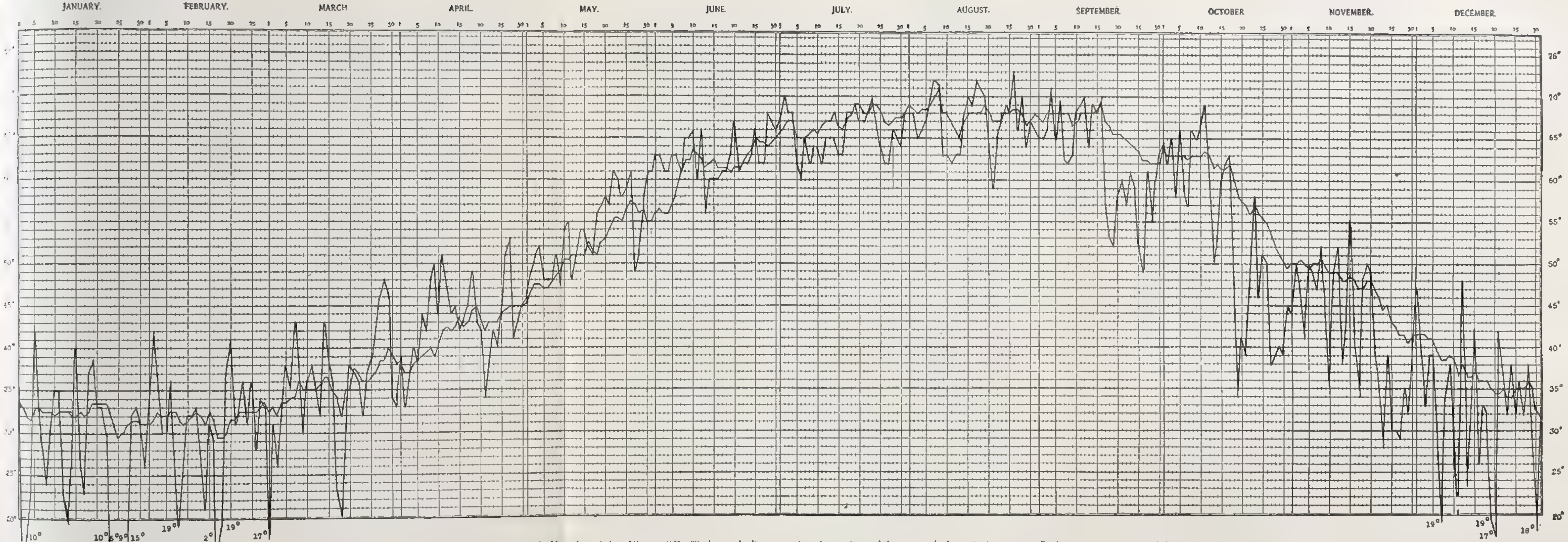

FIG. 4.—Diagram showing temperature of air and water at Woods Hole, Mass., for each day of the year 1922. The less regular line represents air temperature and the more regular line water temperature. Readings are in Fahrenheit, and observations were made at 8 a. m.

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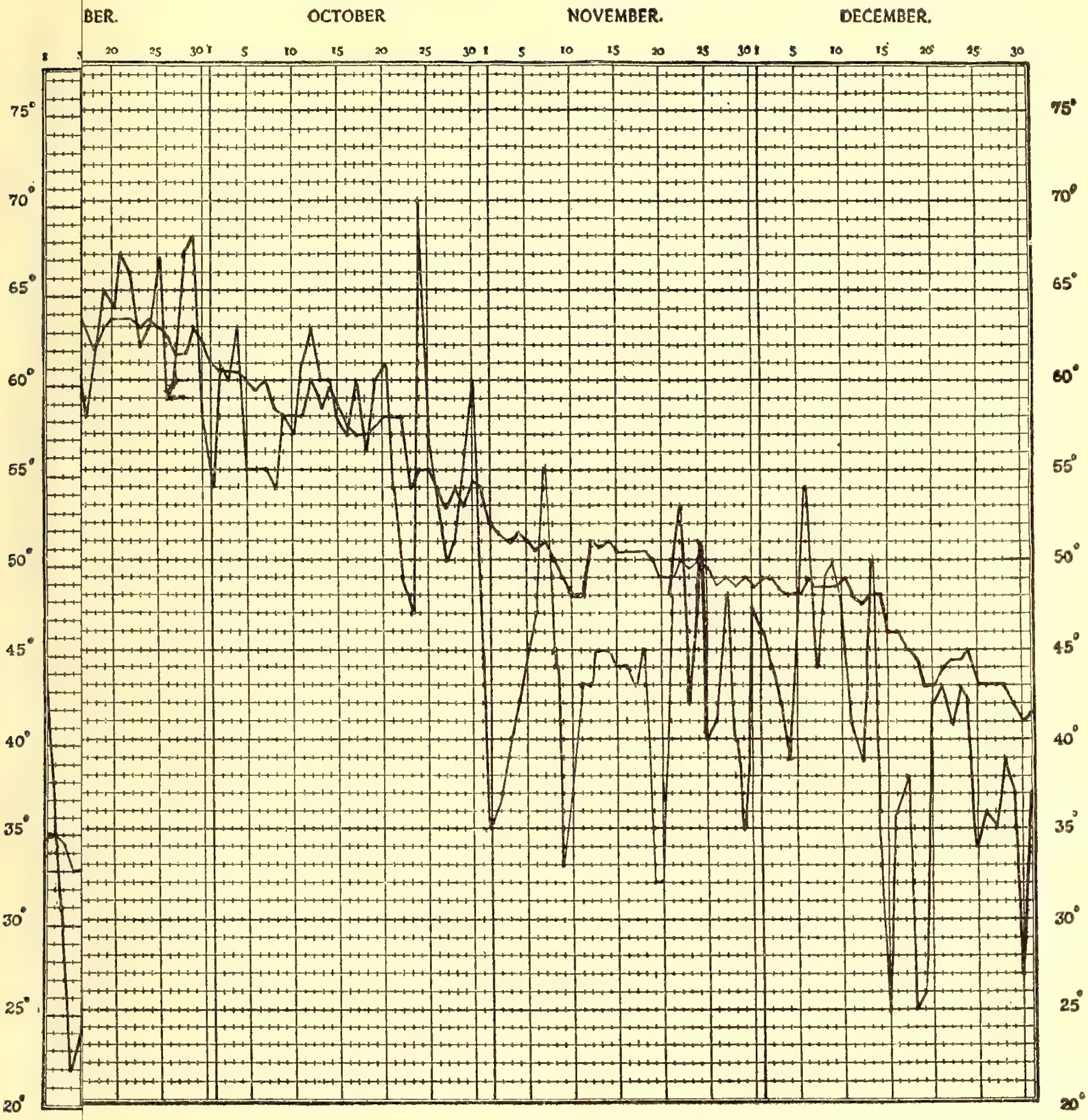

Fahrenheit and observations were made at 8 a. m.

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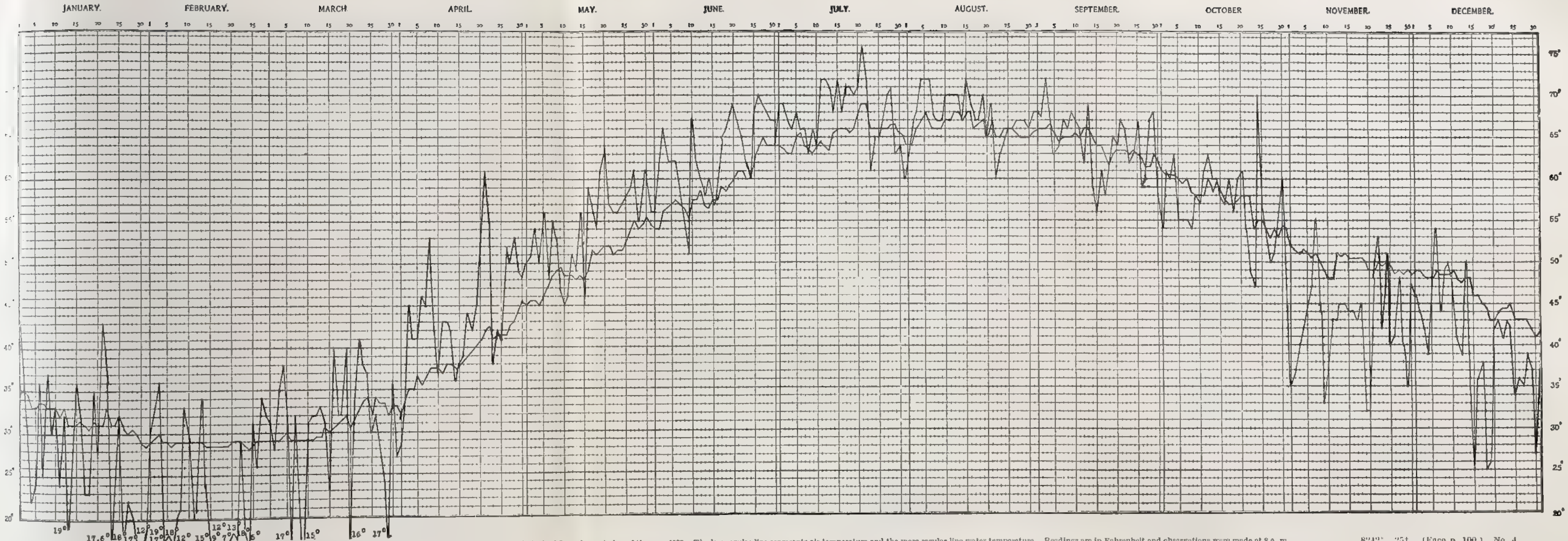

FIG. 5.—Diagram showing temperature of air and water at Woods Hole, Mass., for each day of the year 1923. The less regular line represents air temperature and the more regular line water temperature. Readings are in Fahrenheit and observations were made at 8 a. m.

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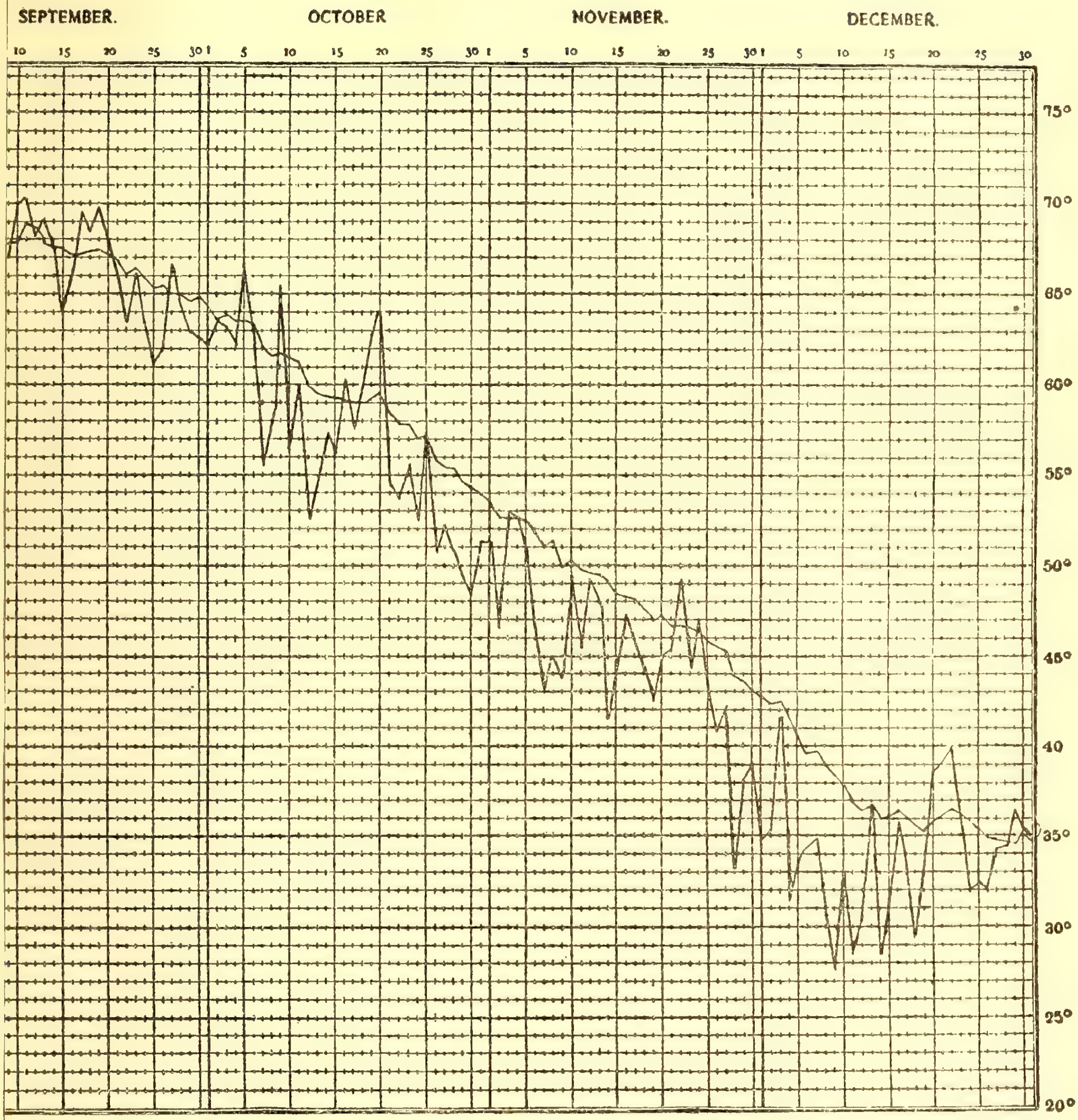

ular line water temperature

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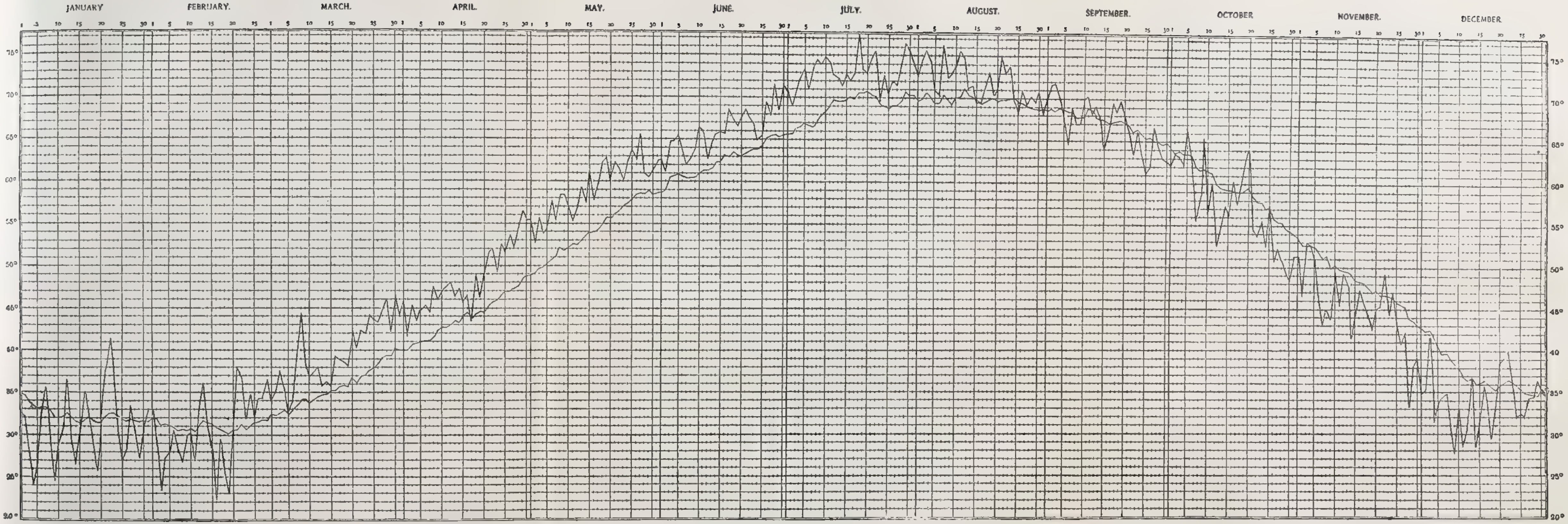

Fig. 6.—Diagram showing mean air and water temperatures at Woods Hole, Mass., for each day of the year, 1902 to 1906, inclusive. The less regular line represents air temperature and the more regular line water temperature

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spring. The warmest months were July and August; the coldest were January, February, and March.

The strong currents rushing through the "Hole" on the flood tide churn the water to such an extent that any change in the temperature of the air affects the bottom water as quickly as it does that of the surface. Table 2 gives a series of temperature observations taken when the temperature was suddenly rising or falling. These show the result of the mixing of the waters.

TABLE 2.—*Surface and bottom temperatures taken at Woods Hole in 1922-23*

Date	° C. at surface	° C. at bottom	Date	° C. at surface	° C. at bottom
July 29, 1922	20.2	20.2	Dec. 17, 1922	3	3
July 30, 1922	21.2	21.2	Dec. 18, 1922	1	1
July 31, 1922	22	22	Dec. 19, 1922	−0.5	−0.5
Aug. 13, 1922	20.5	20.5	Mar. 19, 1923	2	2
Aug. 14, 1922	21.8	21.8	Mar. 20, 1923	−1	−1
Aug. 15, 1922	22	22	Mar. 21, 1923	1.5	1.5
Sept. 6, 1922	22	22	Mar. 22, 1923	2	2
Sept. 7, 1922	21.4	21.4	Mar. 23, 1923	0.3	0.3
Sept. 8, 1922	20.4	20.4			

GENERAL DISCUSSION OF PLANKTON

Marine plankton at Woods Hole falls naturally into two great groups—the oceanic and the neritic—each of which has quite distinct characteristics.

The oceanic plankton consists for the most part of adult animals existing throughout life as a part of the pelagic fauna. The only immature forms normally occurring are the young of these oceanic species. Occasionally larval animals from the neritic plankton are blown out in offshore winds, but this does not occur often. However, it would be impossible to draw a line denoting the boundary between the two types. There exists a broad intermingling area into which each species extends to a point where external conditions form a natural barrier. As all forms are not subject to the same conditions, this wide intermingling zone results.

The neritic plankton, in contrast to the oceanic, consists for the most part of immature forms which in adult life are not a part of this community. There are, of course, many truly pelagic animals common to the littoral zone, but these are usually greatly outnumbered by the temporary intruders, except during the winter and spring months, when the larval forms reach their minima at the same time that many copepods and Sagittæ have their maxima.

Figure 7 illustrates in a general way the constituent parts of the zooplankton at Woods Hole at different times during the year. It will be noticed that the summer and winter plankton are made up of representatives from the same groups. The great difference in the relative abundance of these in the two seasons will be discussed later.

The influx of oceanic species occurs both in summer and winter, although the number of different forms occurring in the colder months is comparatively small. During the summer, however, swarms often appear. Great masses of Sargassum, with its many inhabitants—Physalia and other floating forms—often fill the waters of the Sound after a southeast storm or a continued hard wind. Wheeler noticed that such copepods as *Pontella meadii* and *Anomalocera patersoni* appeared in the tow only after this weather. Dr. H. M. Smith attributes the presence of practically all of the small tropical fish that are taken each year in the Sound and at Katama Bay to southerly winds. The floating Sargassum offers shelter for these animals after they have been passively transported up from the south, and as the weeds are blown inland the fish accompany them. During the winter months such winds are fatal, but in summer the broad expanse of water extending from the coast reaches a temperature as high as that of the stream. Here any forms carried out of their courses can exist very well until the temperature drops in the fall, when all perish.

Variation in the constituent parts of the plankton at Woods Hole during the year

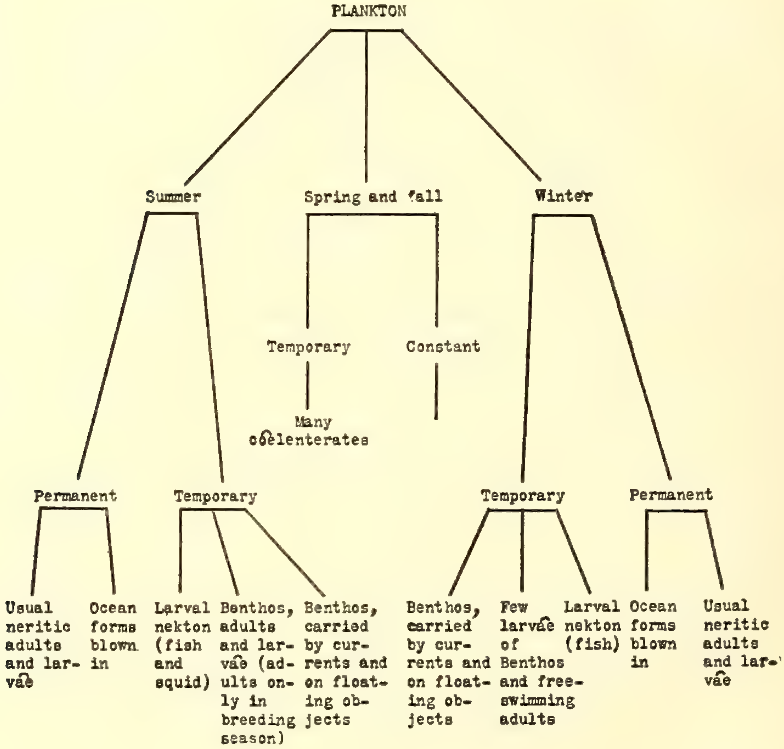
PLANKTON
Summer
Spring and fall
Winter
Temporary
Constant
Many coelenterates
Permanent
Temporary
Temporary
Permanent
Usual neritic adults and larvæ
Ocean forms blown in
Larval nekton (fish and squid)
Benthos, adults and larvæ (adults only in breeding season)
Benthos, carried by currents and on floating objects
Benthos, carried by currents and on floating objects
Few larvæ of Benthos and free-swimming adults
Larval nekton (fish)
Ocean forms blown in
Usual neritic adults and larvæ

FIG. 7

The shallow waters of the immediate region, sheltered as they are by the arm of Cape Cod, respond very quickly to changes of weather, heating rapidly and cooling suddenly. In summer Buzzards Bay is warmer than Vineyard Sound, the maximum temperature occurring at the head of the bay, the minimum around Cuttyhunk. Such conditions continue through August and into October. With the sudden drop in air temperature the bay water responds immediately and results in an exact reversal of the conditions found in August. At this time the water of the bay becomes colder than that of the Sound. That has an important effect on the plankton of Woods Hole, for as long as the bay remains warmer than outside waters all animals carried into it will survive and be carried through the passage during the flood tides. As soon as the temperature drops in the bay the tropical forms entering it will perish and not return to the Sound. Such a condition is very noticeable in the fall, when all Gulf Stream forms suddenly disappear from the plankton of Great Harbor, although they may be taken in abundance in the Sound or at Katama Bay throughout October and November. The arrival of southern forms is usually noted as soon at Woods Hole as in the Sound.

In some parts of the eastern Atlantic a great many animals having a double breeding season are found. These forms appear in the spring and again in the fall. At Woods Hole examples of this group are limited to one phylum—the Cœlenterata. Figure 26 (p. 124) shows clearly that almost all Hydromedusæ common to this region have been taken both in spring and fall, the spring swarm being the largest and lasting for the longest time. The Scyphomedusæ rarely have this double periodical appearance. During the past year, however, early ephyræ of *Aurelia flavidula* were taken in November and again in April. The Ctenophora have been taken in small numbers throughout the winter, but usually swarm in the fall and early spring.

I know of no permanent planktonic animals at Woods Hole having this biannual distribution. Certain copepods are most abundant in the fall or spring, but never at both seasons. Such forms are also plentiful in the winter and have been included in the winter plankton. Two species of importance belong to this group—*Tortanus discaudata* from December to June and *Pseudodiaptomus coronatus* from August to January.

Under normal conditions the zooplankton, although varying considerably in its constituent parts, is always abundant at Woods Hole. The dominant winter or summer form of one year may be totally absent the next, but some other species usually takes its place. During the winter of 1899 and 1900 *Temora longicornis* formed the greater part of the plankton, while in the fall of 1922 and the spring of 1923 hardly an adult specimen was found, the dominant species that year being *Pseudocalanus elongatus*. In the winter of 1923 the temperature of the water remained so high that neither of these winter species had appeared by December 29. *Centropages hematus* and *Acartia bifilosa* constituted the bulk of the collections. Temperature and weather conditions, no doubt, determine to what extent the northern forms pass south of Cape Cod and enter local waters. Almost no cold-water species were found in the early winter of 1923. Such diatoms as *Rhizosolenia alata*, *Skeletonema costatum*, and *Ditylium brightwelli* appeared rarely or not at all, and even the cod apparently sought deeper water, for no young were taken in surface collections.

Normal diatom maxima have no noticeable effect on the larger planktonic forms. When the unusually large swarms of phytoplankton appear, however, the zooplankton decreases rapidly and may even totally disappear for a time. Such conditions are often found during the summer maxima of *Rhizosolenia semispina*. Usually the winter maxima do not affect the larger forms. In the winter of 1922–23 the phytoplankton and zooplankton were both abundant at the same time. At this time *Rhizosolenia alata* was the dominant diatom. In 1923–24 *Nitzschia seriata* occurred in such abundance that the zooplankton disappeared almost entirely from November 16 until February 1. During this period top and bottom collections in the shallow water of the bay and sound yielded nothing but diatoms. The zooplankton was found to be fairly abundant in the deeper waters at the western end of the Sound. As soon as the diatoms declined in numbers the larger forms returned to the shallow water. Figures 8 and 9 show the relative abundance of the zooplankton and phytoplankton in 1922 and 1923.

DIATOMS AND OTHER PLANTS

The diatoms of this locality may be divided into two great groups—the pelagic and the bottom forms. In certain parts of Great Harbor the bottom diatoms are very abundant, and often large numbers occur in surface collections after storms or particularly strong winds. As no fresh-water streams of importance are found in the vicinity of Woods Hole to carry the various chemicals needed for diatom production, much essential material must be carried through the "Hole" from Buzzards Bay by the strong currents. For that reason bottom diatoms were found to be more abundant in eddies and pockets about the entrance of the bay than elsewhere in Great Harbor and not scattered about evenly on the bottom in shallow water, as might otherwise be expected.

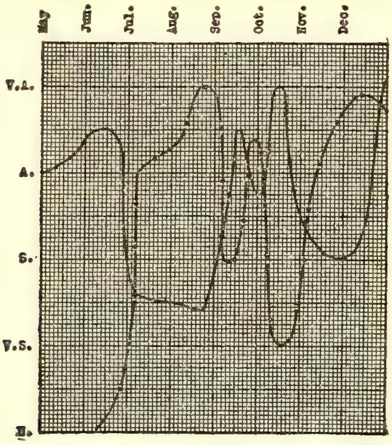

FIG. 8.—Relative abundance of zooplankton and phytoplankton in surface collections from May to December, 1922. ——, zooplankton; —•—, phytoplankton

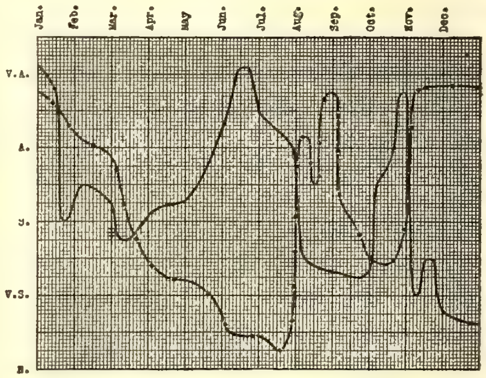

FIG. 9.—Relative abundance of zooplankton and phytoplankton in 1923. ——, zooplankton; —•—, phytoplankton

Together with the dinoflagellates, the pelagic diatoms make up the greater part of the phytoplankton of the region. On all but two occasions the former were far outnumbered by the latter. In every haul made during the year with a No. 20 net diatoms were found. They had regular seasonal variations which were very similar to those of previous years (figs. 10 and 11). There is a regularity in the quantitative variation as well as in the qualitative. The maximum of one year may be larger, smaller, earlier, or later than that of another, but the basic characteristics of the rhythm remain for the most part unchanged. An exception to this rule is found in the appearance of certain oceanic forms, which will be discussed later. Extremely unusual physical factors may even eliminate a part of the cycle, but as soon as normal conditions are restored the progression continues as before. Such was the case in December, 1923, during an unusually warm period (fig. 11). Although quantitatively the winter diatom maxima remained approximately the same as in the previous year, qualitatively it was very different (fig. 10).[1]

To understand the seasonal distribution we must know something of the nature of the various forms that enter Great Harbor. The individual species of neritic phytoplankton are much more widely distributed than the zooplankton, and factors governing their appearance and disappearance are for the most part quite different. As in the case of land plants, the diatoms are able to form organic substances from the various inorganic chemicals. Together with the littoral marine flora they form the basic source of food supply in the sea. Since all plankton animals are consumers and depend solely on the organic materials produced by the plants, the importance of the diatoms and the necessity for information regarding the sources of their production can not be overestimated.

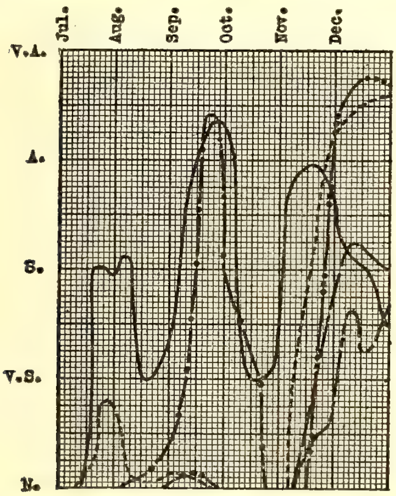

FIG. 10.—Seasonal distribution of most abundant diatoms occurring in surface collections from June to December, 1922. Rhizosolenia excluded. ——, Chætoceros; —·—, *Corethron valdiviæ;* — —, *Ditylium brightwelli;* - - - -, *Leptocylindrus danicus;* —- - —, *Nitzschia seriata;* —· · ·—, *Skeletonema costatum*

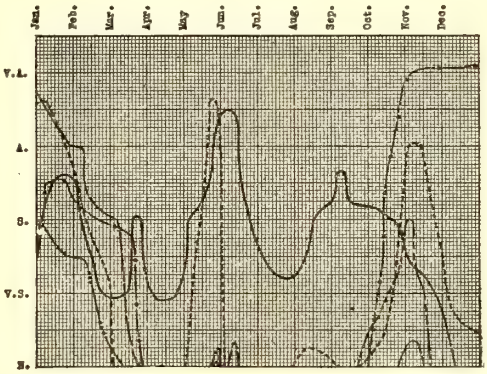

FIG. 11.—Seasonal distribution of most abundant diatoms occurring in surface collections of 1923. Rhizosolenia excluded. ——, Chætoceros; —- - —, *Corethron valdiviæ;* —· · ·—, *Ditylium brightwelli;* - - - - - - - -, *Leptocylindrus danicus;* —·—, *Nitzschia seriata;* — — —, *Skeletonema costatum*

Obviously the two fundamental necessities for diatom growth are sunlight and food material. Secondary factors, such as temperature, salinity, necessary resting periods, etc., limit the geographical and seasonal distribution of certain species but do not usually affect the group as a whole. Physical conditions fatal to one species may be particularly favorable to another. Sunlight limits the vertical range of the species to the narrow zone penetrable by the light (photic zone). This usually does not form a limiting factor of production in local waters or littoral plankton in general.

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[1] See paragraph 1, page 119.

It is of extreme importance in ocean waters, however. Food material is the dominant governing factor for all diatoms. The supply of the substances not common to all sea water arises from two sources—outwash from the land and the replacing of chemicals by the breaking down of the organic substances in the sea. For this reason diatoms are much more abundant in the coastal waters, particularly near the mouths of large rivers (Table 3). No doubt the large amount of disintegrating material often found in coastal water (Bigelow, 1914) after a diatom decline forms an important item in the replacement of essential chemicals such as silicic acid and nitrates, but in comparison with the source of supply from the land it must be rather small. Conversely, in the open ocean it probably forms the most important source in regions where the land areas exert little or no influence. In this respect the oceanic and coastal conditions are widely different.

TABLE 3.—*Distribution of diatoms in Long Island Sound in early March, 1923. Volume determined from vertical hauls*

Locality	Date	Volume	Depth
		c. c.	*Meters*
Throgs Neck	Mar. 5	4	5
Hempstead Harbor	do	6	5
Matinicock Point	do	2. 5	5
Cold Spring Harbor	do	2. 5	5
Pecks Ledge	Mar. 6	4. 5	5
Pine Creek Point	do	4	5
Off Bridgeport Harbor	do	8	5
Stratford Point	do	20	5
Housatonic River, near breakwater	do	12	5
New Haven Harbor	do	10	5
Stations inside of Harbor No. 1	Mar. 7	8	5
Stations inside of Harbor No. 2	do	6. 5	5
Stations inside of Harbor No. 3	do	6. 5	5
Five-fathom Rock	do	7	5
Sachem Head	do	10. 5	5
Hammonasset Point	do	8. 5	5
Falkner Island	do	2	5
Gardiners Bay	Mar. 8	1. 5	5
Little Peconic Bay	do	1	5
Hortons Point	do	4. 5	5
Eaton Point	Mar. 9	3. 3	5
Mid-Sound positions 40-59-54 N.; 73-23-18 W	do	4	5

In the ocean, where uniform physical conditions often exist to comparatively deep water, Nathansohn (1909) found that the diatoms are most abundant in localities where the greatest amount of vertical circulation takes place. (Gran, 1912, gives maximum abundance often as deep as 50 meters and large numbers at 100 meters.) Large quantities of organic material are constantly sinking to the deeper water, and the decomposition of dead plants and animals at these levels sets free the nutritive substances, which are returned to the photic zone in the ascending currents. In anticyclonic systems like that of the Sargasso Sea, where little or no vertical circulation takes place, the diatoms were found to be very scanty. Nathansohn's (1909) theory, no doubt, does not apply to all conditions found in the sea, but remains as the best explanation of the source of production of oceanic diatoms. Ocean currents, which themselves change according to the seasons, cause the diversity of high sea plankton in fixed geographical positions. The occurrence of certain species far beyond the limits of their natural range is usually attributed to currents.

In the coastal waters an entirely different condition of affairs exists. Over the deeper parts of the neritic zone plant life usually is limited to a very thin surface layer, which is differentiated from the deeper water masses by a lesser density and higher temperature. In seasons when there is great outwash from the land the neritic diatoms often form great swarms. In localities where upwelling or vertical circulation takes place under these conditions the surface layers, with their flora, are blown away from the shore and replaced by infertile water drawn up from the bottom layers. The outwash of this fertile water is very favorable to the offshore plankton but causes a diminution of diatoms near the coast, the few that were not carried out having adverse conditions to combat. An inshore wind, on the other hand, heaps up the surface waters and is conducive to luxuriant plant growth. Repeated investigations (Gran, 1912; Nathansohn, 1909; Leder, 1917) of this problem have confirmed the belief that often the rapid appearance and disappearance of diatom maxima is not so much a biological question as a hydrographical one. Gran and Nathansohn in 1909 observed, "We find an intensive plant life, and consequently also an intensive animal life, everywhere at the surface of the sea where an influx of water masses takes place, which has not, or at least has not immediately previous, served as a source of nourishment for phytoplankton."

Sometimes a diatom society is found in summer in the lower strata, with its higher density and lower temperature, which was present in the surface waters earlier in the spring. Such conditions are common among the zooplanktonic forms and are occasionally found among the diatoms. Miss Ogilvie found the same diatoms in the lower strata off the south coast of Ireland in August as were present at the surface from January to April. This is an indication that certain neritic forms, which are apparently periodical in their occurrence, might remain as permanent members of the plankton if conditions of existence were more uniform. This is interesting in view of the fact that many investigators have considered that a resting period (spore formation) is a necessary part of the existence of truly littoral species.

It is impossible in local waters accurately to determine the real relationship of the local conditions of existence and the development of the diatoms, because the currents often cause variations much greater than those actually due to conditions of existence. Gran (1912), realizing this, substituted a study of the rate of growth as a measure of production in place of quantitative chemical analysis of food materials present in the water. In the vicinity of Woods Hole, where the currents are unusually strong, the production would have to take place at an extremely high rate in order to maintain itself were it not for the many "pockets" of quiet water which are supplied with abundant land outwash. In certain less protected sections of the coast this may be an important factor in the sudden disappearance of certain species. As soon as the rate of production declines the species is unable to maintain itself, and this inability to replace the numbers carried away by the currents may cause the maxima to disappear long before the food supply is exhausted.

In dealing with the conditions of production it is very important to know just where the production of floating forms takes place before attempting to explain their appearance or disappearance. Two theories are now held. One contends that all production of pelagic neritic diatoms takes place off the coasts, the sudden swarming in inland rivers and small bays being the result of tides and winds. The second theory is that production also takes place within certain limits in inland waters. To be sure, winds may blow quantities of diatoms into open harbors and small bays, but this does not explain the conditions as they are often found. Since Woods Hole is a particularly unfortunate location to observe the factors of diatom production, I shall cite results obtained in Long Island Sound in 1922 and 1923.

The first indication of local production was the variation in the species of pelagic diatoms found in the different harbors and river mouths along one shore. Had winds carried them there, one would expect to find the same species in all the harbors. This was not the case except during the greatest swarms, when the Sound seemed filled with a single species. In succeeding cruises it was noted that the volume of phytoplankton in the vertical hauls taken at the mouths of rivers and in harbors connected with inland streams was much greater than that of the mid-Sound or harbors containing no land outwash. Table 3 (p. 106) shows the centrifuged volume, in cubic centimeters, taken with a Hensen medium-sized vertical net at various points in the Sound. The predominant species was *Skeletonema costatum.* A strong west wind had prevailed for several days before the collections were made. Had the distribution of diatoms resulted from this they should have occurred most abundantly along the southeast shore near the eastern end. The table clearly shows that the greatest swarms occurred at the mouths of the rivers and harbors where the most land drainage is carried into the waters. The salinity is low in all parts of the Sound, and for that reason the diatoms do not penetrate far into the mouths of the rivers and harbors. No great tides sweep the Sound at any place except at the "race," and even there Galtsoff found that 8 miles is the maximum distance that the water is carried in a single tide.

Another source of evidence can be found in Peck's (1896) report on diatom collections in Buzzards Bay. His stations were laid in two lines, one at right angles to the other, extending the length and width of the bay. A series of observations at various points along these courses showed that the greatest abundance of diatoms occurred at the two inshore stations. The other two ends of the courses were located in Vineyard Sound and the rapids at Woods Hole, and therefore are not considered. He concluded from these records that there was a shallow area of diatoms surrounding all the shores of Buzzards Bay. A glance at Figure 12 will show that the two inshore points he selected (indicated by ▲) were near the mouths of the greatest harbors of the entire Bay. The large rivers at the head of the Bay empty their waters near Peck's north station, while the waters of the Acushnet and Nasketucket Rivers join at the point of his western station. Undoubtedly Peck would have found his hauls less rich if he had selected spots along the eastern shore.

A noticeable characteristic of neritic plankton flora is the variety of diatoms that is usually found in every swarm. One or two species predominate, but the many other species occurring in smaller numbers make up the so-called "diatom society." Allen, in 1920, made the following statement:

> Detailed study of the records has clearly shown the important fact that when there is an increased production of the most prominent forms there is also increased production of the less prominent forms and an increase in the number of different forms. Such facts naturally lead to the assumption that conditions favorable to high productivity of diatoms in the sea affect a large number of forms in the same way. They also lead to the inference that determination of the species that shall lead in production is due largely to the biological factors, such as rapid multiplication and vigorous development.

As most rules have exceptions, so, too, an exception to this rule is often found at Woods Hole during the summer months when the oceanic diatom (*Rhizosolenia semispina*) occurs in such abundance that almost every other form of animal and plant life disappears for a time. The occurrence of this interesting species will be discussed later.

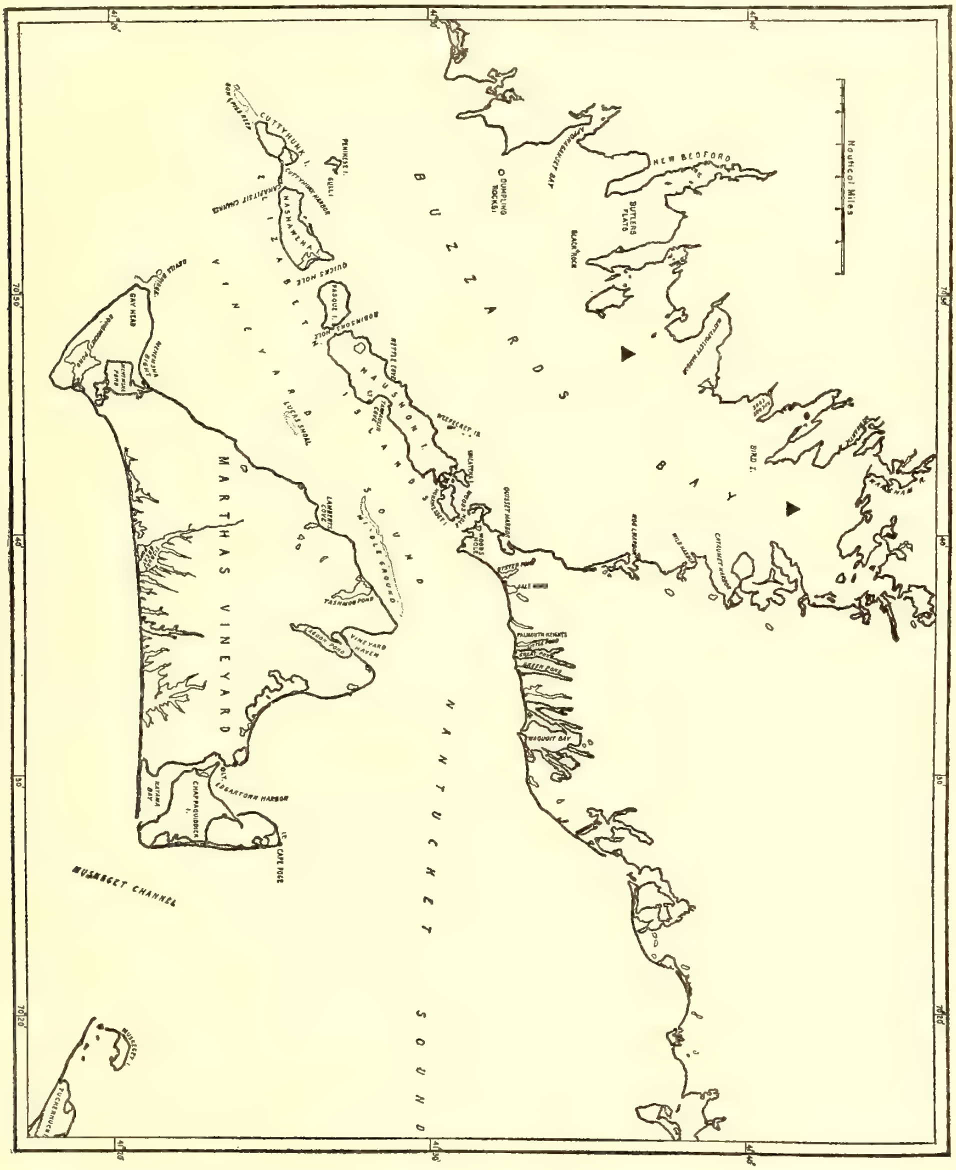
BUZZARDS BAY
VINEYARD SOUND
NANTUCKET SOUND
MARTHAS VINEYARD
ELIZABETH IS.
CUTTYHUNK I.
NASHAWENA I.
PASQUE I.
NAUSHON I.
NEW BEDFORD
GAY HEAD
VINEYARD HAVEN
EDGARTOWN HARBOR
CHAPPAQUIDDICK I.
CAPE POGE
MUSKEGET CHANNEL
MUSKEGET I.
TUCKERNUCK I.
WOODS HOLE
QUISSETT HARBOR
FALMOUTH HEIGHTS
WAQUOIT BAY
BIRD I.
DUMPLING ROCKS
BUTLERS FLATS
BLACK ROCK
QUICKS HOLE
LUCAS SHOAL
MIDDLE GROUND
LAMBERT COVE
TASHMOO POND
OYSTER POND
SALT POND
GREEN POND
WEEPECKET IS.
Nautical Miles

Fig. 12.—Map of Buzzards Bay and Vineyard Sound

The diatom spores are no doubt at all times exceedingly numerous in local waters and are carried about by the currents and winds. When conditions become favorable for those already present or those transported to a harbor or river mouth where rich food material has been washed from the land, the spores germinate and increase rapidly in numbers. The development will continue until the food supply is exhausted or other unfavorable conditions arise. In discussing spore formation in diatoms Gran (1912) stated:

> When we subsequently find the same species once more in abundance, we have every reason for surmising that the resting spores on the bottom were the principal source from which these forms have been derived. Ability to form resting spores must be of the utmost importance for the existence of the species in coastal waters. The chief difference between coastal seas and the ocean, so far as hydrographical conditions are concerned, lies in the extreme and rapid changes in such fundamental conditions of existence as salinity and temperature in coastal waters. Resting spores, therefore, must be the means by which many species continue in coastal seas, notwithstanding the fact that there conditions of existence are favorable only for a limited portion of the year. The Arctic diatoms, for instance, which sometimes are to be found in the plankton of the Skager-Rak, are very easily affected by a rise in temperature, but their development takes place during the winter months from February to April, when the temperature is at its minimum. In the summer they are not to be seen, but their resting spores are then most probably on the bottom. In the same way a whole series of warmth-loving species pass through the winter as resting spores and are to be found along our shores only in the warmest months of summer and autumn.

As in the case of the littoral pelagic fauna, the winter diatom flora throws an interesting light on the effect of the arm of Cape Cod on the winter forms in local waters. In summer the cold waters north of the cape form a barrier for southern neritic plankton. Samples taken by Bigelow in August, 1922, in Massachusetts Bay, contained the same diatoms as those which appeared in Woods Hole in greatest abundance in December. No doubt many of the northern diatoms are carried south in the summer, but the sudden rise in temperature apparently is sufficient to cause them to form resting cells or die. The effect of a slight change of temperature was evident at the end of March, 1923, when the winter forms suddenly disappeared. In winter, on the contrary, those carried south find a favorable climate with a supply of food material that has accumulated since the disappearance of the summer forms. Together with local winter neritic species they form a maximum the extent of which depends upon the supply of silicates, nitrates, etc., in the water, and remain until the food is exhausted or the temperature becomes unfavorable. In this way the arm of Cape Cod forms a southern barrier for northern littoral plankton only in summer and not at all times, as in the case of many benthonic species.

If this assumption were based upon the neritic diatoms alone, it could hardly hold, because, combined with the evidence of the existence of diatom spores in all coastal waters, the factor of temperature alone could explain the condition, and transportation by currents around Cape Cod would not be necessary. However, as the most abundant species (*Rhizosolenia alata*) north of the cape in August was a truly oceanic form and proved to be the first to appear in large numbers at Woods Hole, I think it justifiable to attribute it to the currents, just as in the case of the northern copepods appearing about the same time which were certainly transported in that manner.

None of the so-called "pulses" which Allen observed on the Pacific coast occurred at Woods Hole in 1922 or 1923. The seasonal curves rose and fell evenly. On April 3, 1913, Bigelow found the waters of Massachusetts Bay filled with diatoms. These were not evenly distributed but appeared as brownish-colored bands alternating with clear areas. It may be that patches like these formed the pulses of which Allen speaks, for his collections were on the open coast and taken from the end of a wharf past which the belts of uneven abundance would drift.

The seasonal variation of the diatom maxima and the appearance of oceanic species in local waters can be understood best by considering the geographical position of Woods Hole as compared with other areas of the eastern and western Atlantic. Steuer (1911) found that in general the maxima of the various species, both neritic and oceanic, is closely related to temperature, and thus varies according to the latitude. It has long been known that on both the European and American coasts the most luxuriant diatom growth does not take place in the warmest months even as far north as Norway and Newfoundland.

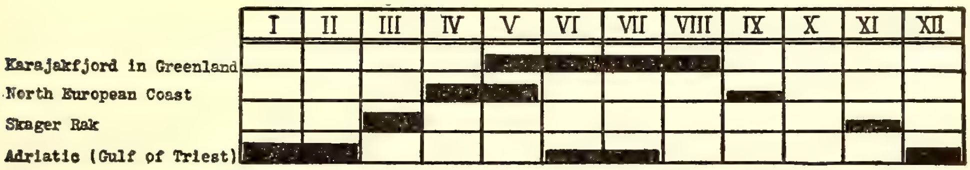

FIG. 13.—Schematic diagram of the seasonal distribution of the diatom maxima in the northern and southern parts of the eastern Atlantic. After Steuer

At Karajakfjord, in Greenland, Vanhöffen (1897) found only one maximum, from May until the beginning of September. South of this there occurs the typical spring and fall maxima, which retreat farther and farther from the warmest seasons as one approaches the Tropics. Steuer (1903) found that this constant succession of diatom maxima toward the south necessarily leads to the assumption that somewhere in the south there will be a meeting of the two maxima in winter, and this was found to occur in the Adriatic Sea by Leder (1917), Steuer (1903), Stiasny (1908), and Gran (1909) (fig. 13). A smaller maximum was also found to occur in June and July. Conditions on the American coast are surprisingly similar to those of the eastern Atlantic (fig. 14).

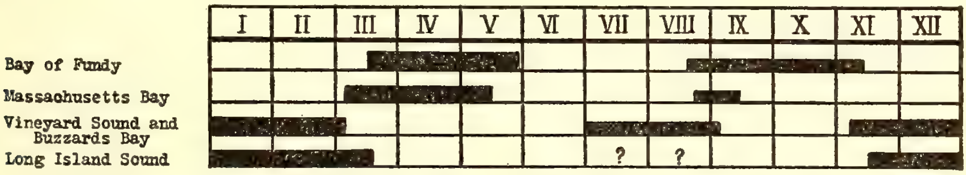

FIG. 14.—Schematic diagram of the seasonal distribution of the diatom maxima on the western Atlantic coast

Observations in eastern Canadian waters by Bailey, MacMurrich, and Fritz show that the greatest maxima occur in the spring and fall. Bigelow (1917) commented on the similarity of the diatom distribution in the Gulf of Maine and that of the North Sea, Irish Sea, and Skager-Rak. He also found a great maxima in Massachusetts Bay in April and early May, 1913, and a smaller one in September, 1915, and one in late August, 1922.

The striking effect of the arm of Cape Cod on the plankton is again evident here, for within 20 miles of latitude of Massachusetts Bay conditions similar to those of the Mediterranean and Adriatic Seas are found in Buzzards Bay. Here and throughout the shallow waters south of Cape Cod a rich winter diatom plankton starts usually in November and continues until March, reaching a maximum in December. This compares very closely with the maxima found year after year at Trieste. Corresponding to the short summer maximum of that region, a summer swarm occurs also at Woods Hole, starting usually in July and remaining until September. A comparison of the seasonal distribution and breeding seasons of the zooplankton of the two regions shows that the conditions at Trieste are of a more southerly nature than in this region, although it is farther north. Its relation to the Mediterranean makes the reason for this obvious. The summer maximum is very variable, because the local neritic species play a minor part, the greater part consisting of a single oceanic form (*Rhizosolenia semispina*). Obviously, conditions beyond the limits of the adjacent coast have much to do with the appearance of this form. In 1922 and 1923 it was particularly abundant (figs. 15

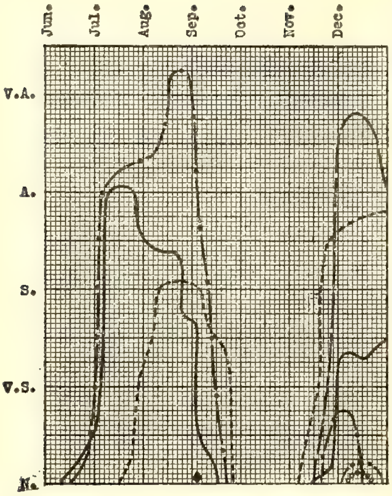

FIG. 15.—Occurrence of Rhizosolenia in surface collections from May to December, 1922. —•—, *Rhizosolenia semispina;* --------, *R. setigera;* ———, *R. shrubsolei;* — — — —, *R. alata genuina;* ♦. *R. alata gracillima;* ooooooooo, *R. styliformis;* —•••—, *R. færœensis*

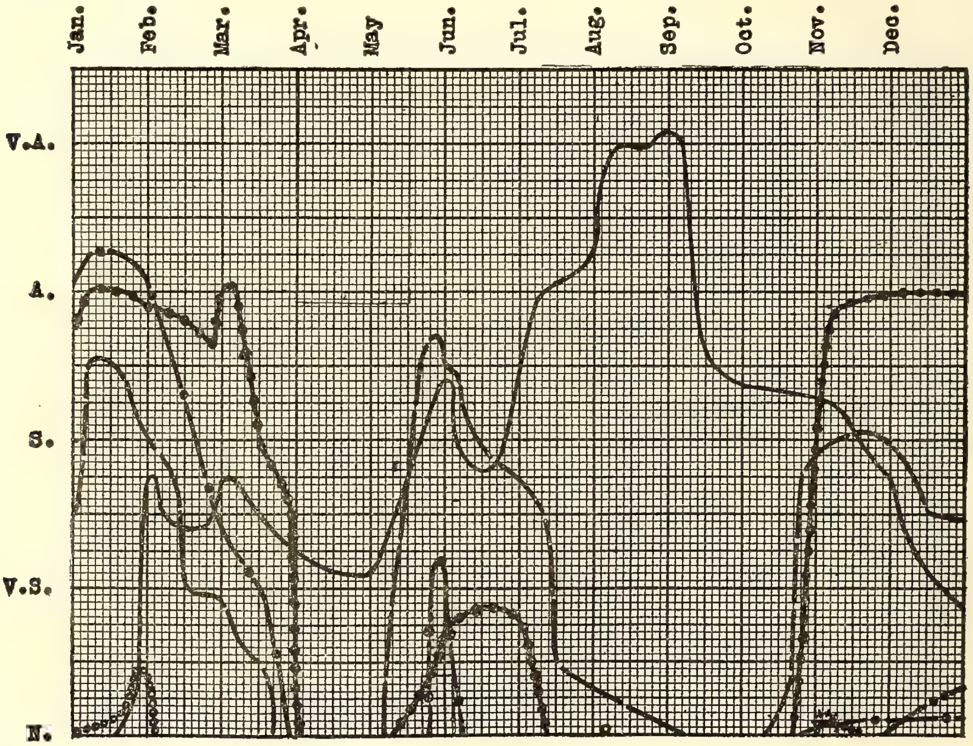

FIG. 16.—Occurrence of Rhizosolenia in surface collections of 1923. ———, *Rhizosolenia semispina;* —•—•—•—, *R. setigera;* — — — —, *R. shrubsolei;* —•—, *R. alata genuina;* ooooooo, *R. styliformis;* ++++++++, *R. calcar avis;* —••—, *R. delicatula*

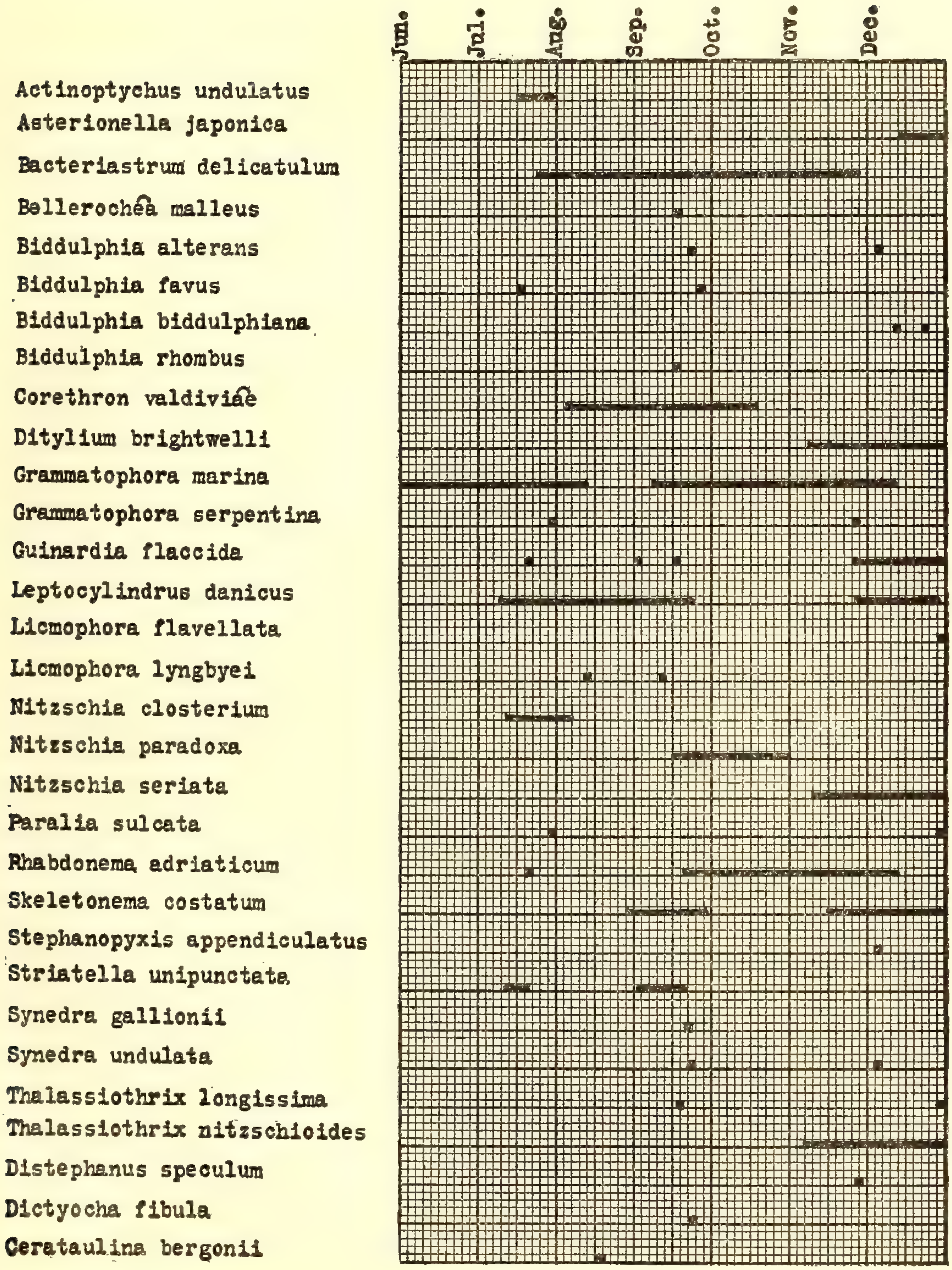

FIG. 17.—Distribution of diatoms and Silicoflagellata in 1922 (excluding Chætoceros and Rhizosolenia)

and 16), filling the waters of the bay and the eastern part of Vineyard Sound. The seasonal distribution of diatoms in Long Island Sound in 1922–23, during the winter months, was found to be very similar to that of Woods Hole except that the swarms appeared slightly later.

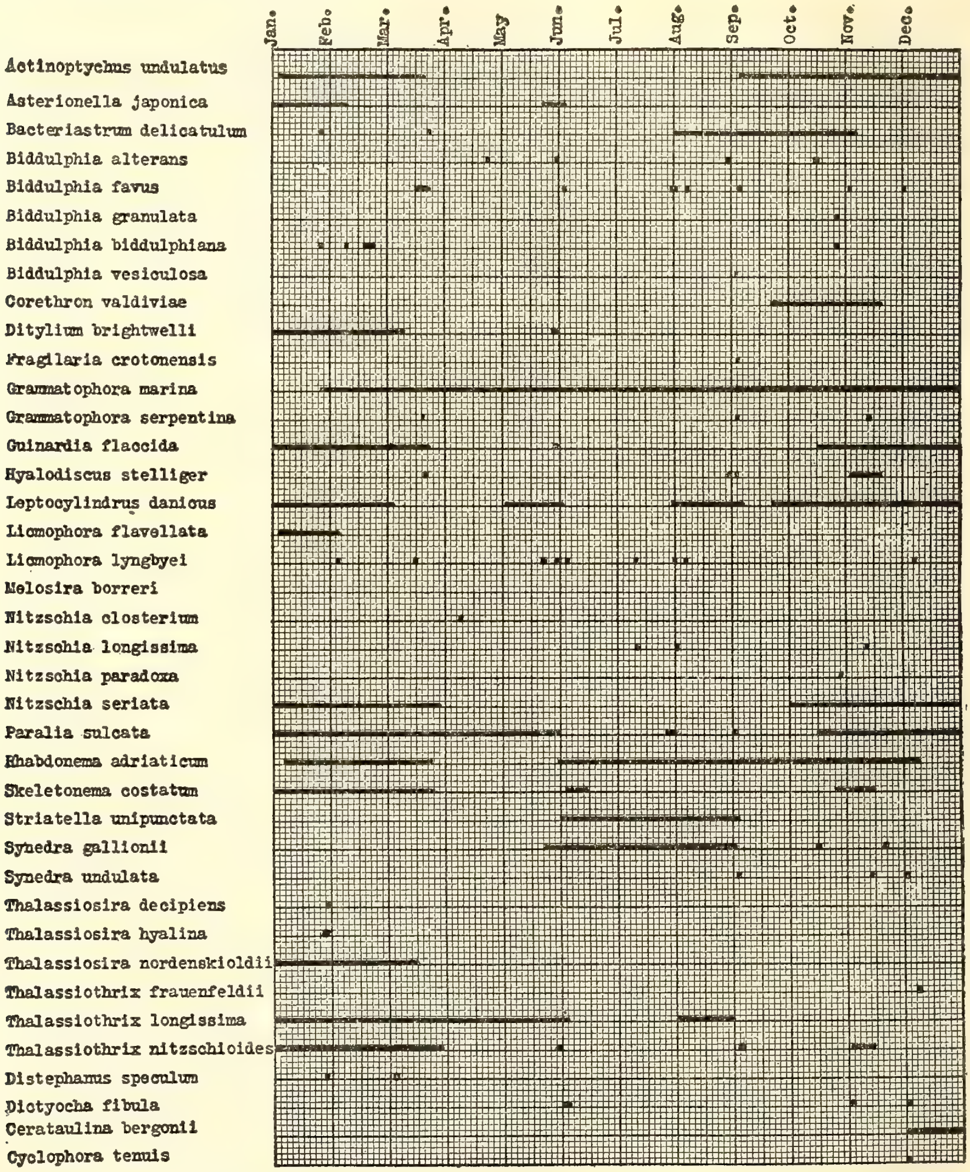

FIG. 18.—Distribution of diatoms and Silicoflagellata in 1923 (excluding Chætoceros and Rhizosolenia)

The pelagic diatoms of the Woods Hole region may be grouped under three headings—tychopelagic, oceanic, and neritic. The tychopelagic group is made up of semi-bottom forms, which often occur in coastal waters in enormous numbers. They are carried about by the winds and tides, usually without relation to any particular season (figs. 17 and 18). The following common tychopelagic forms appeared in the surface collections of the past year: *Actinoptychus undulatus*, *Biddulphia alterans*, *B. favus*, *B. granulata*, *B. biddulphiana*, *B. rhombus*, *B. vesiculosa*, *Hyalodiscus stelliger*, *Melosira borreri*, and *Paralia sulcata*. All of these species are temperate forms.

The oceanic and neritic diatoms that have a distinct periodicity in occurrence may be grouped according to the latitudes in which they are distributed. This method, originated by Cleve, has been used by almost all planktonologists. The various groups into which Cleve divided the characteristic plankton diatoms are represented at Woods Hole by the following species:

Neritic	Boreal Arctic	Chætoceros mitra.
		Nitzschia closterium.
		Thalassiosira hyalina.
		nordenskiöldii.
	North Temperate	Chætoceros danicum.
		debile.
		diadema.
		sociale.
		teres.
		Leptocylindrus danicus.
		Licmophora flavellata.
		Nitzschia longissima.
		Rhizosolenia færoeensis.
		setigera.
		Skeletonema costatum.
		Stephanopyxis appendiculatus.
		Synedra gallionii.
		Thalassiosira decipiens.
		Thalassiothrix nitzschioides.
	South Temperate	Asterionella japonica.
		Bacteriastrum varians.
		Chætoceros cinctum.
		contortum.
		didymum.
		laciniosum.
		lorenzianum.
		schüttii.
		Ditylium brightwelli.
		Fragilaria crotonensis.
		Grammatophora marina.
		serpentina.
		Guinardia flaccida.
		Nitzschia paradoxa.
		Rhabdonema adriaticum.
		Rhizosolenia calcar avis.
		delicatula.
		shrubsolei.
		Striatella unipunctata.
		Synedra undulata.
	Tropical	Bellerochea malleus.
		Rhizosolenia calcar avis.
		shrubsolei.

Oceanic	Boreal Arctic	Chætoceros atlanticum.
		boreale.
		criophilum.
		decipiens.
		Nitzschia seriata.
		Rhizosolenia hebetata (semispina).
		Thalassiothrix longissima.
	Temperate	Chætoceros densum.
		peruvianum.
		willei.
		Rhizosolenia alata f. genuina.
		f. gracillima.
		Thalassiothrix frauenfeldii.
	Tropical	Chætoceros coarctatum.
		peruvianum.
	Antarctic	Corethron valdiviæ.

In 1922 the summer swarm was composed almost entirely of members of the genus Rhizosolenia (figs. 15 and 16). *Rhizosolenia semispina* and *R. shrubsolei* appeared about June 15, followed in July by *R. setigera.* The latter two species were never as numerous as the former. *R. semispina* increased rapidly until July 5, when the swarms literally filled the waters of the bay and sound, clogging even the coarsest plankton nets with a slimy brown ooze. Shortly after this it began to decline, disappearing about September 9. The 1923 maximum was very similar, except that the two minor species terminated their season earlier than in the previous year, while *R. semispina* declined more slowly, remaining in small numbers throughout the fall and early winter.

The occurrence of this species at Woods Hole during the summer months is rather interesting. It is a northern oceanic form, known from both the Arctic and Antarctic regions, and was found by Ostenfeld (1913) to thrive best in the areas of the North Atlantic where cold currents seek southward. It is particularly abundant in the spring in the region of the Labrador Current about Newfoundland and Nova Scotia. Bigelow (1917), in July, 1914, found a large maximum off Marthas Vineyard at the time when the great swarms appear in local waters. In 1923 the author found them extending from Cape Cod along the eastern side of Marthas Vineyard to Nantucket and in Vineyard Sound as far as Menemsha Bight. None were found at the western end of the Sound or in the waters about No Man's Land. This indicates that they enter the region from the northeast, as would be expected. Miss Ogilvie (1923) found a maximum in July, 1920, off the south coast of Ireland.

The summer maximum at Woods Hole, then, is not wholly dependent upon local conditions. Either of the two neritic species, *Rhizosolenia shrubsolei* and *R. setigera* might dominate if hydrographical conditions prevented the appearance of *R. semispina.* The abundance of the latter species will depend partly on the numbers blown into the bay and sound and partly upon the food material present there. Although it is a northern form it must have an extremely broad temperature range, because its distribution in Buzzards Bay in 1923 showed conclusively that great production was taking place there at a time when the temperature was ranging from 19 to 21° C.

As the numbers of *Rhizosolenia semispina* diminished in the late summer of 1922, Chætoceros (fig. 19) increased, but lasted for only a short time. Another diatom (*Corethron valdiviæ*) then became very abundant and reached its maximum about September 20 (fig. 10, p. 105). A rapid decline took place after this, followed by another Chætoceros increase. In 1923 Corethron appeared on September 21, reaching its maximum on November 3 (fig. 11, p. 105). All available records for Corethron show it to have its flowering season in the fall. In European waters Ostenfeld (1913) reports it to be most abundant in autumn. Ogilvie (1923) found it abundant on the south coast of Ireland in July, 1920, and in August and November, 1921. Fritz (1921) records it from the Bay of Fundy in October, 1916, and in September and October, 1917.

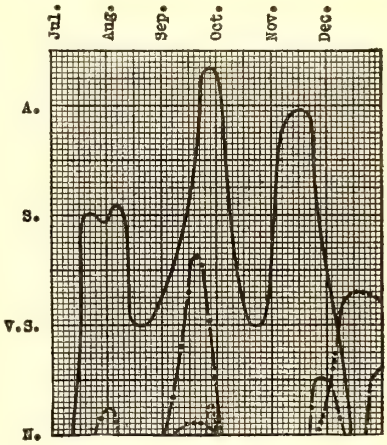

FIG. 19.—Occurrence of the more abundant species of Chætoceros from May to December, 1922. -----, *Chætoceros decipiens;* —···—, *C. didymum;* —·—, *C. laciniosum;* ——, *C. schüttii;* —-—, *C. sociale*

The winter maximum at Woods Hole consists usually of a greater variety of abundant species than that of the summer. In 1922 many species appeared suddenly about November 8. As the season progressed different forms predominated on different days, but all were usually abundant. At first *Rhizosolenia alata f. genuina,* a temperate oceanic

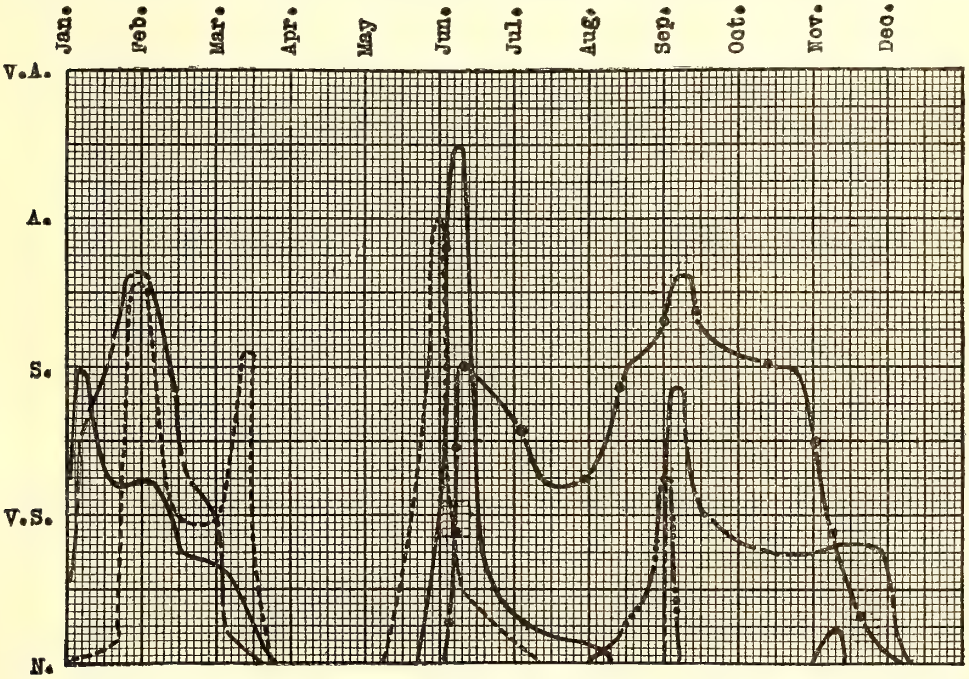

FIG. 20.—Occurrence of the more abundant species of Chætoceros in surface collections of 1923. -----, *Chætoceros decipiens;* ——, *C. didymum;* —···—, *C. laciniosum;* —·—, *C. schüttii;* —-—, *C. sociale*

species, proved to be the most conspicuous form (fig. 15). Later this was replaced by *Leptocylindrus danicus* and *Skeletonema costatum.* Both of these species are north temperate neritic forms, which are supposed by Ostenfeld to exist all the year round on the bottom, being carried up among the plankton in the flowering season and during high winds. The distribution at Wood Hole appears to substantiate this very well (figs. 10 and 11, p. 105). The winter flowering season is evident, and the scattered occurrence throughout the year can be best explained by Ostenfeld's theory. Although very similar to tychopelagic forms, these two species differ in that they multiply greatly while members of the plankton. Other abundant members of the 1922–1923 winter society were *Ditylium brightwelli, Thalassiothrix nitzschioides, Rhizosolenia setigera, R. shrubsolei,* and *Chætoceros sociale,* all of which are neritic species (figs. 10, 11, etc.). Two oceanic forms

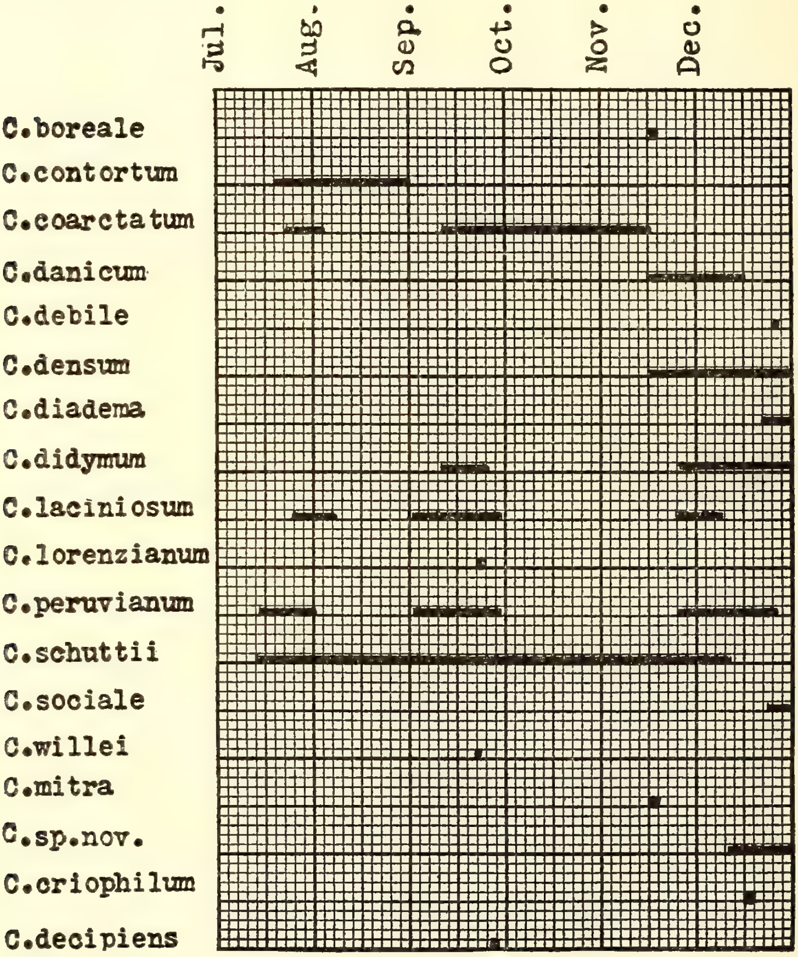

FIG. 21.—Distribution of Chætoceros from June to December, 1922

(*Nitzschia seriata* and *Chætoceros decipiens*) were fairly numerous at times but always played a minor rôle.

As previously stated, unusual physical factors may cause great variation in the time when the maxima appear as well as in the constituent parts. Such was the case in the winter of 1923 (figs. 4 and 5, p. 100), when, after an unusually warm season, although quantitatively the winter diatom maximum was approximately the same as in the previous year, qualitatively it was very different. *Rhizosolenia alata,* the first dominant species to appear in the 1922 swarm, occurred only as scattering forms in 1923; while *Nitzschia seriata,* a rather scanty form in 1922, outnumbered all others during the entire winter maximum by more than 1,000,000 : 1 (fig. 11, p. 105). Certain other members of the 1922 maximum, of which *Ditylium brightwelli* is an example, did not appear at all.

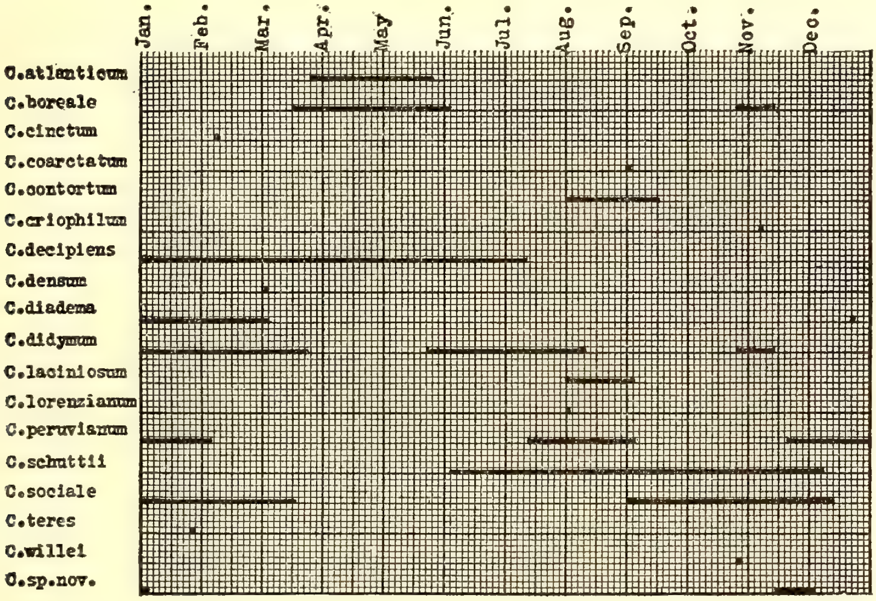

FIG. 22.—Distribution of Chætoceros in 1923

The absence of *Rhizosolenia alata* (excepting scattering forms) might have been caused by the extremely mild weather of the early winter. However, as it is a common oceanic species there are many other factors which may have affected it. Certainly the unusual temperature influenced the neritic forms. During the short time when the temperature was normal in the early fall (fig. 11) many species—*Chætoceros didymum,* Skeletonema, Leptocylindrus, etc. (figs. 21 and 22)—appeared and began their normal flowering season. When the unusual temperature conditions continued, however, they declined and remained as scattering forms or disappeared; but one species, *Rhizosolenia setigera,* which has an extremely wide temperature range (fig. 16), apparently thrived with Nitzschia during the period.

Nitzschia seriata is an Arctic oceanic species which often appears in large numbers off the Norwegian coasts. It is very variable in occurrence, being present some years and entirely absent in others. In all areas investigated it forms its greatest maxima in the spring. In the spring of 1923 it reached its maximum in January, remaining throughout March. The following winter it arrived slightly earlier and increased rapidly, swarming early in November (figs. 10 and 11, p. 105). Throughout the winter season it remained as the most dominant species.

The distribution of diatoms during the past year may have been unusual. Certainly two seasons' changes are not sufficient from which to draw conclusions. However, as all available records for past years seem to indicate similar summer and winter maxima, it is probable that yearly variations will be in the date of the appearance of these same species and not so much in the species themselves. Winds may carry in unusual oceanic species, but these may be considered accidental visitors whose appearance again can not be predicted. The following diatoms appeared in surface collections of the past year:

Actinoptychus undulatus (Bailey).
Asterionella japonica, Cleve.
Bacteriastrum varians, Lauder.
Bellerochea malleus (Brightwell).
Biddulphia alterans (Bailey).
B. biddulphiana (Smith).
B. favus (Ehrenberg).
B. granulata, Roper.
B. rhombus (Ehrenberg).
B. vesiculosa (Agardh).
Cerataulina bergonii, Peragallo.
Chætoceros atlanticum, Cleve.
C. boreale, Schütt.
C. cinctum, Gran.
C. coarctatum, Lauder.
C. contortum, Schütt.
C. criophilum, Castracane.
C. danicum, Cleve.
C. debile, Cleve.
C. decipiens, Cleve.
C. densum, Cleve.
C. diadema (Ehrenberg).
C. didymum, Ehrenberg.
C. laciniosum, Schütt.
C. lorenzianum, Grunow.
C. mitra (Bailey).
C. peruvianum, Brightwell.
C. schüttii, Cleve.
C. sociale, Lauder.
C. teres, Cleve.
C. willei, Gran.
Corethron valdiviæ, Karsten.
Cyclophora tenuis, Castracane.
Ditylium brightwelli (West).
Fragilaria crotonensis (M. Edwards).
Grammatophora marina, Kützing.
G. serpentina, Ehrenberg.
Guinardia flaccida (Castracane).
Hyalodiscus stelliger, Bailey.
Leptocylindrus danicus, Cleve.
Licmophora flavellata, Smith.
L. lyngbyei (Kützing).
Melosira borreri, Greville.
Nitzschia closterium, Smith.
N. longissima (Brebisson).
N. paradoxa, Grunow.
N. seriata, Cleve.
Paralia sulcata (Ehrenberg).
Rhabdonema adriaticum, Kützing.
Rhizosolenia alata f. genuina (Gran).
R. alata f. gracillima (Cleve).
R. calcar avis, Schultze.
R. delicatula, Cleve.
R. færœensis, Ostenfeld.
R. hebetata var. semispina (Hensen).
R. setigera, Brightwell.
R. shrubsolei, Cleve.
R. styliformis, Brightwell.
Skeletonema costatum (Greville).
Stephanopyxis appendiculatus, Ehrenberg.
Striatella unipunctata (Lyngbye).
Synedra gallionii, Ehrenberg.
S. undulata (Bailey).
Thalassiosira decipiens (Grunow).
T. hyalina (Grunow).
T. nordenskiöldii, Cleve.
Thalassiothrix frauenfeldii (Grunow).
T. longissima, Cleve and Grunow.
T. nitzschioides, Grunow.

After southerly storms during the summer Vineyard Sound is often filled with floating *Sargassum bacciferum* (Turner). This is a tropical plant from the Gulf Stream, which is usually accompanied by a community of pelagic animals. As it has never been known to reproduce in the region, it is probable that all die in the fall when the temperature of the water drops. Although not true oceanic plankton, this plant must be mentioned, for many pelagic forms enter Woods Hole attached to it. A local species (*Sargassum filipendula* Agardh) is commonly found attached to rocks and piles below the low-water mark in the harbor, but this has no relation to the plankton.

PROTOZOA

The protozoa were omitted in the present investigation, with the exception of the large forms that at times were numerous enough to form an important part of the plankton. Unless special methods are used no real estimate of the abundance of the many minute organisms of this phylum can be made. Lohmann (1911) showed that at least 50 per cent of the living forms entering the finest silk nets available pass through the meshes and escape. It is very possible to grow cultures of protozoa, as Peck has already done at Woods Hole, but it was not my purpose to create artificial complexes, so that method was not employed. It is of value, however, in obtaining many of the rarer species.

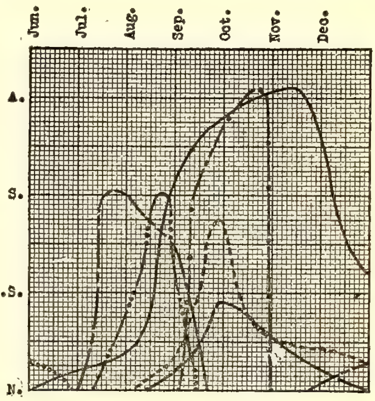

FIG. 23.—Occurrence of most abundant forms of Protozoa in surface collections from June to December, 1922. ——, *Ceratium tripos;* - - - - - - -, *C. macroceros;* — — —, *C. fusus;* ooooooo, *Peridinium depressum;* — - —, Tintinnopsis sp.; — • —, *Heterophrys sol;* — • • • —, *Peridinium oceanicum* var. *oblongum*

Certain of the larger protozoa were very abundant at times, particularly *Ceratium tripos*, *Peridinium depressum*, *P. oceanicum*, and several species of the genus Tintinnopsis. The distribution of these animals often appears to be very definitely related to that of the plants. During a heavy diatom maximum very few of the larger forms appear, particularly the dinoflagellates. It may be that as soon as the plants have exhausted their food supply and disappeared the protozoa that utilize the nitrates and not the silicates increase rapidly. Just why they should follow immediately after the diatoms is a puzzle, but it is clearly noticeable and can readily be seen by comparing Figures 15, 16, 23, and 24. Thus, after the great *Rhizosolenia semispina* maximum of the summer, *Ceratium tripos* swarmed, followed closely by *C. macroceros* and *C. fusus* in smaller numbers. These would have reached a maximum earlier, I believe, had it not been for the influx of *Corethron valdiviæ*, which came in September, 1922 and 1923. For that reason their normal high point was never reached. Throughout November and December, 1922, they declined as the winter diatom maximum increased, disappearing shortly before the diatoms ceased in April. This may have been caused by the gradual rise in temperature at that time.

Within three days after the bulk of the diatoms disappeared two species of protozoa fairly swarmed in the plankton. The most abundant of these was an unidentified species of the genus Tintinnopsis, although the other (*Peridinium depressum*) was also taken in great numbers. Hundreds of the thimblelike cups of Tintinnopsis could be seen at one time in the field of the microscope. Certain other forms were noticed at different periods throughout the year, but they never formed an important part of the plankton.

A second species of Peridinium (*Peridinium oceanicum* var. *oblongum*) had a maximum in the fall of both years. This is a much smaller form than *P. depressum* and was never present in such large numbers. In 1922 it appeared on July 9, reaching its maximum late in August and disappearing about Spetember 15. In 1923, as in the case of almost all the planktonic forms of that season, the period was later, commencing about September 2 and remaining until November 20.

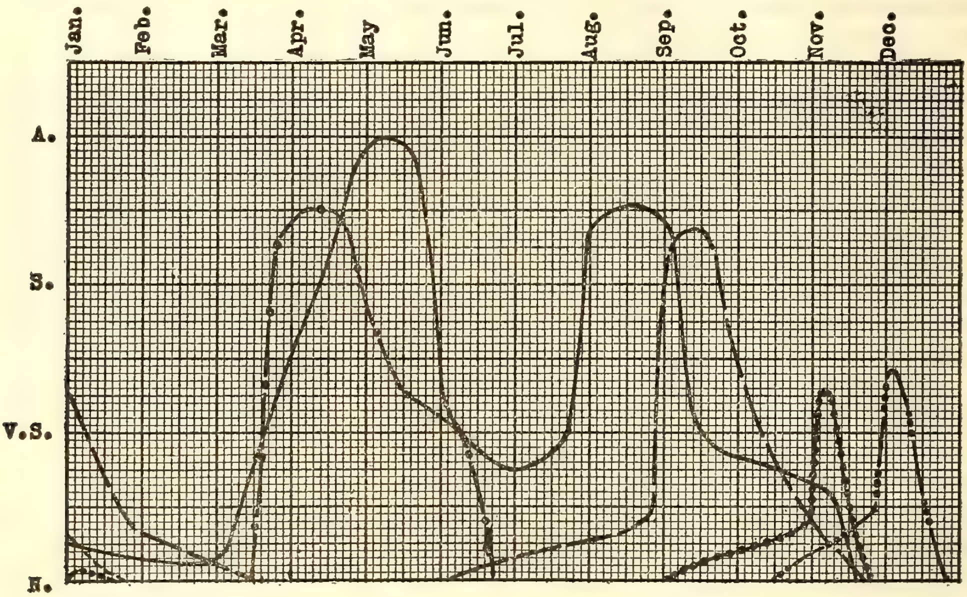

Fig. 24.—Occurrence of most abundant forms of Protozoa in surface collections of 1923. — — —, *Ceratium tripos;* - - - - - - -, *C. macroceros;* —...—, *C. fusus;* —.—, *Peridinium depressum;* -.-.-.-.-, *P. oceanicum* var. *oblongum;* ——, Tintinnopsis sp

During the fall maximum of Ceratium the water fairly blazed with light when disturbed. They caused the net to gleam like a lantern, and often bottom forms not normally taken at the surface were attracted to it.

An interesting radiolarian (*Heterophrys sol*) also occurred in the fall. During September and October, 1922, the numbers gradually increased until they became exceedingly abundant, often being found in bunches of 20 or 30 specimens. After the 26th of October the number rapidly diminished until November 1, when the last one was seen. None appeared in the collections of 1923.

Of the Silicoflagellata, *Distephanus speculum* and *Dictyocha fibula* occurred as scattering individuals throughout the year except in the warmest months. Distephanus was most abundant from November, 1922, to March, 1923, and Dictyocha appeared from September to May. Many Foraminifera appeared, usually after a storm. These, however, sank quickly to the bottom again and were rarely taken in surface collections in calm weather. Some six species were distinguished, but positive identification was impossible because there was not sufficient literature available at the time.

The following protozoa were identified from the surface collections of 1922–23:

Acineta tuberosa, Ehrenberg. March 4, 1923.
Ceratium fusus (Ehrenberg). See Figures 23 and 24.
C. longipes (Bailey). February to June, 1923.
C. macroceros (Ehrenberg). See Figures 23 and 24.
C. tripos (Müller). See Figures 23 and 24.
Dictyocha fibula, Ehrenberg.
Distephanus speculum, Hæckel.
Glenodinium compressa, Calkins. March 4, 1923.
Gonyaulax tricantha, Jörgensen. April 21, 1923.
Gymnodinium gracile, Bergh.
Heterophrys sol, Ehrenberg.
Peridinium depressum, Bailey. See Figures 23 and 24.
P. oceanicum var. oblongum, Aurivillius. Figures 23 and 24.
Tintinnopsis davidoffi, Daday. October 14, 1922.
Tintinnopsis sp. See Figures 23 and 24.

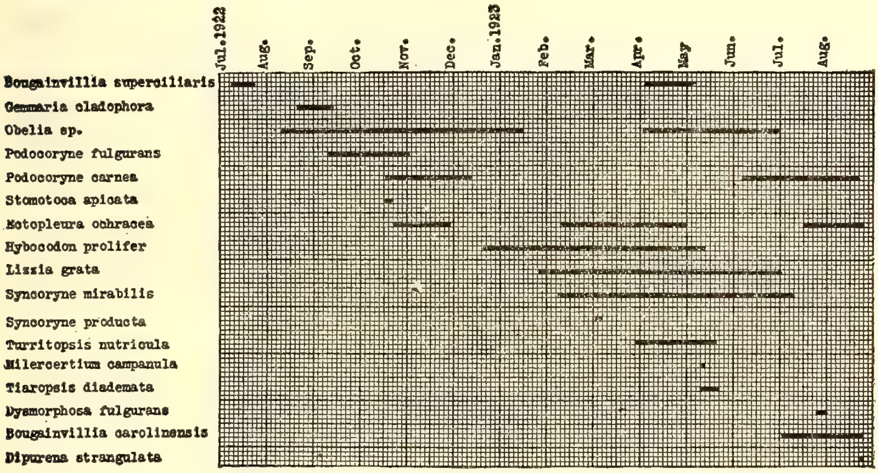

FIG. 25.—Occurrence of Hydromedusæ in surface collections from June, 1922, to December, 1923

CŒLENTERATA

One hundred and sixty species of cœlenterates were recorded from the Woods Hole region by Sumner. Of these, 132 were Hydrozoa, 5 were Scyphoza, and 8 were Ctenophora. Thirty-eight species are listed in the tow records of Vinal N. Edwards for the years 1893–1907. Figures 25, 26, and 27 show the maximum occurrence of the more common species, while in Table 4 the rarer forms, together with the particular dates of appearance, are noted. The records of the more common Scyphomedusæ and ctenophores are also recorded on individual charts.

The diagrams show clearly that there are definite seasons of occurrence for the various species of cœlenterates. In most cases the species have a long spring maximum and also a short one in the fall. Such a semiannual appearance is not

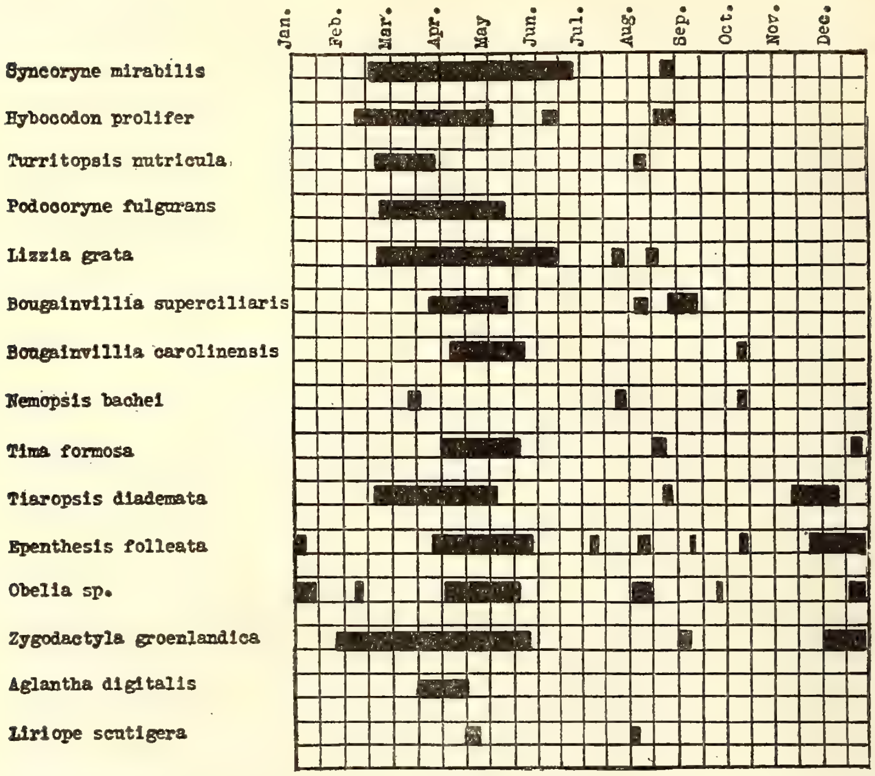

FIG. 26.—Hydromedusæ occurring commonly in surface towings. Maximum occurrence based on records of years 1893 to 1907

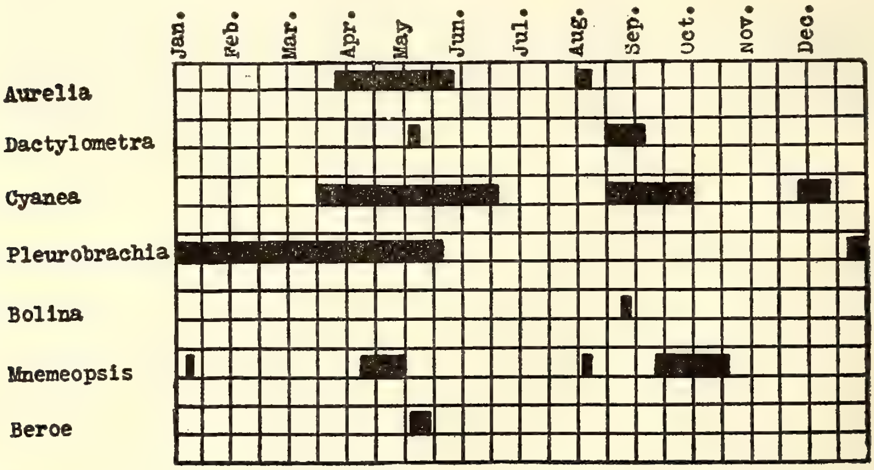

FIG. 27.—Maximum seasonal distribution of Scyphomedusæ and Ctenophora, based on records of the years 1893 to 1907. See individual charts for Aurelia, Pleurobranchia, and Mnemeopsis

common among marine animals. *Bougainvillia superciliaris*, *Hybocodon prolifer*, *Nemopsis bachei*, *Tiaropsis diademata*, *Podocoryne fulgurans*, and *Tima formosa* are examples of Hydromedusæ having double seasonal distribution. However, hardly a single species that occurs normally in the spring has not also been taken in small numbers in the fall. With the exception of *Podocoryne carnea* none of the summer visitors have this biannual appearance.

A regular progression of the more common species of Medusæ can usually be noticed in the spring. *Hybocodon prolifer* appears first, followed closely by *Syncoryne mirabilis* and *Lizzia grata*. In early July, as these species reach the end of their season, *Podocoryne carnea* and *P. fulgurans* appear, followed in August by *Dipurena strangulata* and *Bougainvillia carolinensis*. The summer and fall species always occur in smaller numbers than the spring forms. Certain forms appear to be distributed throughout the year. *Epenthesis folleata* has been recorded for almost every month.

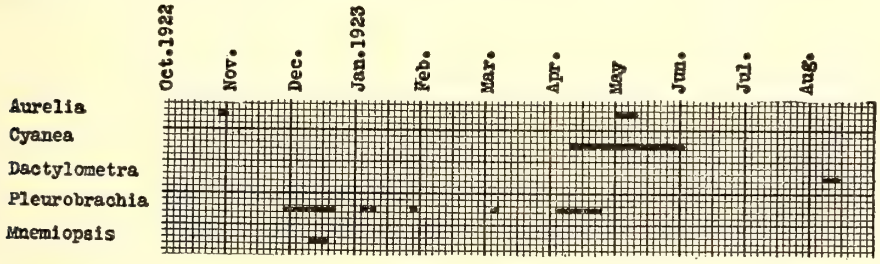

FIG. 28.—Occurrence of Scyphomedusæ and Ctenophora in surface collections from June, 1922, to December, 1923

Three species of Scyphomedusæ are taken frequently in surface collections (fig. 28). The most common (*Aurelia flavidula*) appears usually in March, April, and May, although ephyræ have been taken from August to October.

TABLE 4.—*Occurrence of uncommon Hydromedusæ in surface towings*

Species	Date	Abundance
Ectopleura ochracea	Aug. 9, 1904	Few.
Corymorpha pendula	Apr. 28 and 29, 1905	Many.
Stomotoca apicata	Apr. 27, May 1, and Aug. 15, 1903	Few.
Staurostoma laciniata	Apr. 9, 1906	Do.
Eutima mira	Apr. 7, 1902	Many.
Oceania languida	May 16 and 17, 1904	Do.
Genus Clytia (probably C. bicophora)	May 16, 1905	Few.
Rhegmatodes tennuis	Sept. 2 and 14, 1907	Many.
Aglantha conica	Apr. 24, 25, and 30, and May 2, 1906	Few.

Every year in Waquoit Bay immense swarms of strobelias and ephyræ of Aurelia appear before the ice leaves. They also occur in varying abundance in all local protected coves and shallow bays where eel grass (*Zostera marina*) grows in abundance. The young apparently rests on the bottom during the ebb tide, rising with the flood tide. During this period the water is often filled with them, while a few hours later none may be seen. In the spring of 1923 ephyræ were particularly numerous at Waquoit Bay, although only a single specimen appeared in my collections from Great Harbor. By April the medusæ had increased in size, varying from 1 to 3 inches in diameter. Shortly after this they disappeared. The disappearance probably took place when all strobilization had stopped and the currents carried the medusæ away. Occasionally at a later date swarms of large adults have been seen in Vineyard Sound or Buzzards Bay. No adults were noted during the past summer (1923) in local waters, although large swarms of mature Aurelia were seen on two occasions in neighboring localities—Mount Hope Bay on July 14, and at the entrance of Oyster Bay in early August.

It is difficult to understand how the planulæ get back into the harbors (particularly Waquoit Bay) in such large numbers when apparently no adults remain in the region. The eggs can not be deposited before the medusæ leave in the summer because the animals are not mature at the time. I have never seen a mature specimen in Waquoit Bay. There seem to be but two possibilities—either enough adults remain in the bay until the breeding season (perhaps on the bottom) to repopulate it or the planulæ are drifted in by the tide. I believe that the first assumption is more probable; that is, that sufficient adults remain to restock the waters even though none may be seen at the surface. The difficulties besetting the second possibility make it almost impossible except under rare conditions when Vineyard Sound is filled with adult Aurelia at the correct time. In the first place the medusæ are entirely at the mercy of the winds and tides. They may be widely scattered in coastal waters or piled together in great banks, as described by Hargitt and Agassiz. The latter author considered that the animals gathered together in the breeding season, but this is not probable. After storms large numbers of disks, minus lobes and tentacles, of both Aurelia and Cyanea are often found at the surface in local waters. All are destroyed before winter arrives. As the sexes are separate in Aurelia it is largely a matter of chance whether fertilization takes place at all, because the adults are likely to be widely separated before reaching sexual maturity. Under these conditions it would hardly be possible for the species to maintain itself, because it is apparently beset with more difficulties than the cod and has a proportionately much smaller number of eggs. Therefore, the few adults that remain in the bays may serve to maintain the species during seasons when fertilization in the open waters is impossible, while a fortunate gathering of adults during the breeding season may account for the enormous swarms present in certain years. This dependence on a chain of circumstances to bring the sexes together at the right time probably goes far to explain the irregularities in this and allied neritic species.

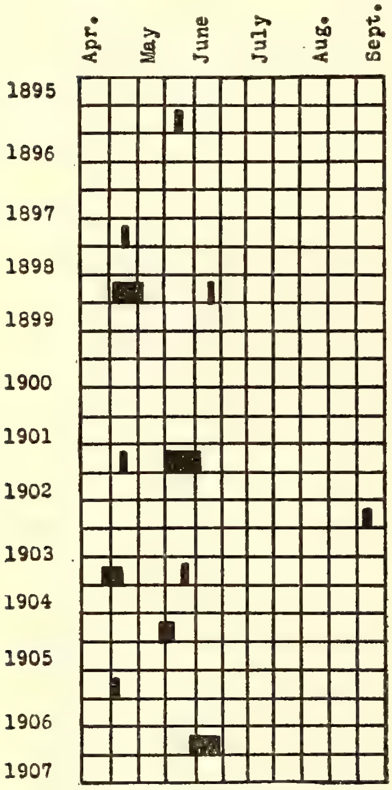

FIG. 29.—Occurrence of *Aurelia flavidula* during successive years, 1893 to 1907

Cyanea capillata appears commonly in spring and fall, but not in as great numbers as Aurelia. On April 14, 1923, the first specimen appeared. Throughout May and early June specimens varying from 10 to 50 mm. could be seen daily at the surface in Great Harbor, often in large numbers. Alexander Agassiz observed great numbers of Cyanea at the surface between 4 and 5 a. m. at Provincetown. "By 7 a. m. all had returned to deeper waters, although not a breath of air had disturbed the surface." A variation in abundance was clearly noticeable in local waters during the past year, but the vertical migration did not affect the whole group, some specimens occurring at the surface throughout the day. Their numbers increased rapidly, however, during the flood tide. It may be that Agassiz's observations could be explained on that basis. Unfortunately no records of the tide were given.

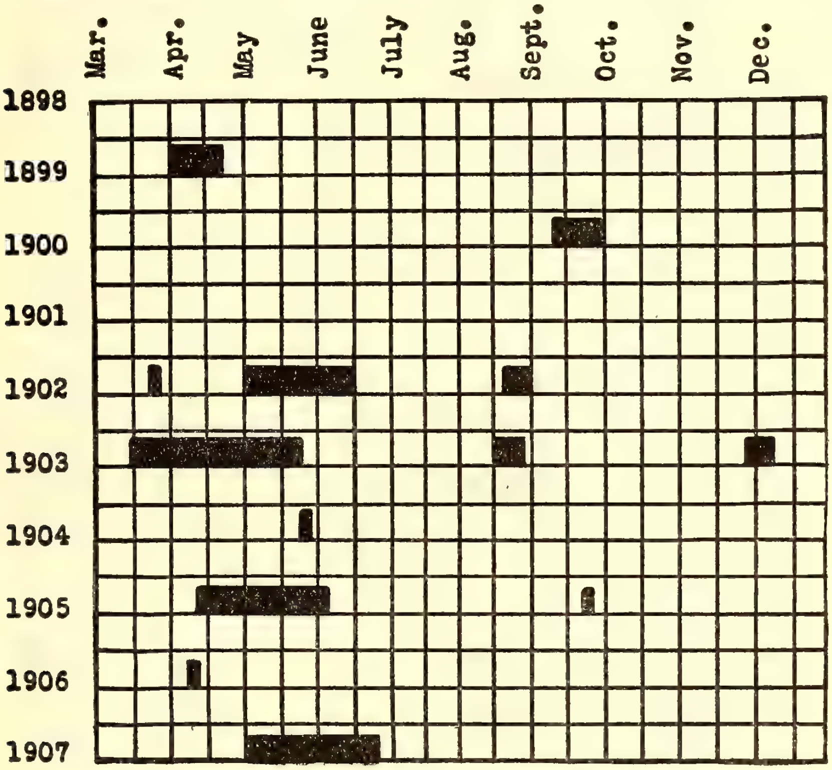

FIG. 30.—Occurrence of *Cyanea capillata* during successive years, 1893 to 1907

Dactylometra quinquecirra occurs occasionally in Vineyard Sound and Buzzards Bay, although in very small numbers. In Narragansett Bay it is usually very abundant in September and October. On August 8, 1923, a single specimen was taken in Lackeys Bay, and several days later a few were observed in Vineyard Sound. George Gray records large numbers taken on several occasions, together with *Salpa democratica-mucronata*, off Nonamesset Island at the mouth of Great Harbor. This species is known to be nocturnal, and for this reason the local appearance may be greater than the records indicate because very little night collecting has been done except from the Fisheries dock. This species appears to prefer the relatively impure water of bays and rivers, rarely being taken in coastal waters.

Ctenophora present a very difficult problem to anyone attempting to determine seasonal distribution. They are found scattered throughout the year in many places. In this region the limits of the seasonal appearance are very definite, although the abundance varies greatly. *Pleurobrachia pileus* (figs. 27, 28, and 31) appears in late December and remains until the latter part of May. The occurrence during 1923 was very scattered. For a few weeks in December, 1922, they were abundant in all collections and then diminished gradually until February. From February until April few were seen, but on April 1 many appeared and remained throughout the month. In certain seasons immense swarms occur. During the latter part of April, 1895, Mr. Edwards often noted that the nets filled in a few minutes with these jelly-like organisms.

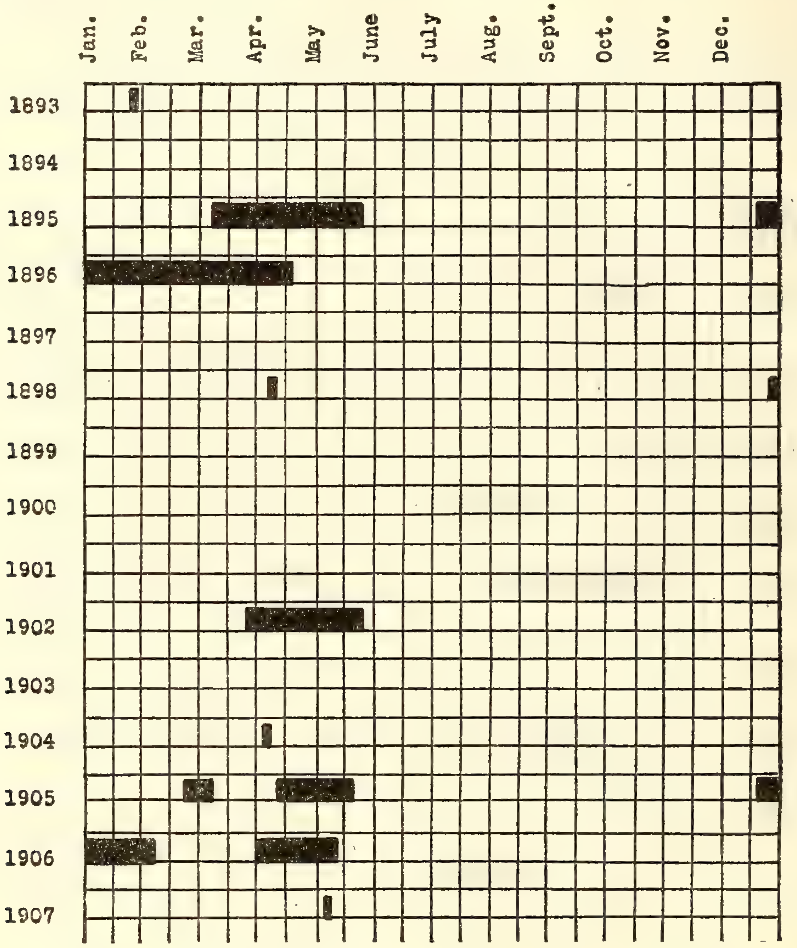

FIG. 31.—Occurrence of *Pleurobrachia pileus* during successive years, 1893 to 1907

Mnemiopsis leidyi appears in smaller numbers at Woods Hole. In Long Island Sound there is a very large fall maximum in August and a large winter maximum in December and January. They are rarely found in Buzzards Bay in large numbers, and were taken in only 3 years during the 15 for which the author has records. During the past year a single specimen appeared on December 11 and three on December 15. Cape Cod is, no doubt, the northern limit of this species, and its appearance in local waters depends upon the winds. Specimens taken this spring were stragglers from the winter maximum of more southern waters. No remnants of the fall maximum found their way into Great Harbor in 1922 (figs. 27, 28, and 32).

Bolina alata has been taken at Woods Hole in September by Mr. Edwards. Agassiz described it as being one of the commonest species in Massachusetts Bay, but rare south of Cape Cod. None was seen in Great Harbor during the past year.

Beroe cucumis is usually very rare in this region, although Mr. Gray found it abundant on one or two occasions in late April and May. It is a northern form whose appearance in local waters is accidental, depending upon strong easterly winds.

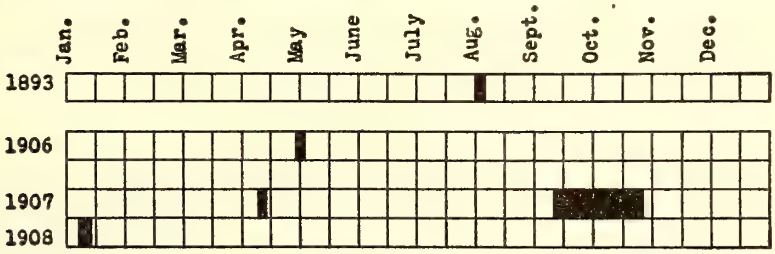

FIG. 32.—Occurrence of *Mnemiopsis leidyi* during successive years, 1893 to 1908

The following cœlenterates appeared during the years 1922 and 1923:

Hydromedusæ:
- Bougainvillia carolinensis (McCrady).
- B. superciliaris, Agassiz.
- Dipurena strangulata, McCrady.
- Ectopleura ochracea, Agassiz.
- Gemmaria cladophora, Agassiz.
- Hybocodon prolifer, Agassiz.
- Lizzia grata, Agassiz.
- Melicertum campanula, Agassiz.
- Obelia sp.
- Podocoryne carnea, Sars.
- P. fulgurans (Agassiz).
- Stomotoca apicata (McCrady).

Hydromedusæ—Continued.
- Syncoryne mirabilis, Agassiz.
- S. producta, Hargitt.
- Tiaropsis diademata, Agassiz.
- Turritopsis nutricula, McCrady.

Scyphomedusæ:
- Aurelia flavidula, Peron and Lesueur.
- Cyanea capillata, Eschscholtz.
- Dactylometra quinquecirra (Desor).

Ctenophora:
- Mnemiopsis leidyi, Agassiz.
- Pleurbrachia pileus (Fabricius)

Cœlenterates recorded from 1893 to 1907 were:

- Hydromedusæ:
  - Aglantha conica, Hargitt.
  - A. digitalis, Müller.
  - Bougainvillia carolinensis (McCrady).
  - B. superciliaris, Agassiz.
  - Clytia (probably C. bicophora), Agassiz.
  - Corymorpha pendula, Agassiz.
  - Ectopleura ochracea, Agassiz.
  - Epenthesis folleata, McCrady.
  - Eutima mira, McCrady.
  - Hybocodon prolifer, Agassiz.
  - Liriope scutigera, McCrady.
  - Lizzia grata, Agassiz.
  - Nemopsis bachei, Agassiz.
  - Obelia sp.
  - Oceania languida, Agassiz.
  - Podocoryne fulgurans (Agassiz).
  - Rhegmatodes tenuis, Agassiz.
- Hydromedusæ—Continued.
  - Staurostoma laciniata (Agassiz).
  - Stomotoca apicata (McCrady).
  - Synocoryne mirabilis, Agassiz.
  - Tiaropsis diademata, Agassiz.
  - Tima formosa, Agassiz.
  - Turritopsis nutricula, McCrady.
  - Zygodactyla grœnlandica (Peron and Lesueur).
- Scyphomedusæ:
  - Aurelia flavidula, Peron and Lesueur.
  - Cyanea capillata, Eschscholtz
  - Dactylometra quinquecirra (Desor).
- Ctenophora:
  - Beroe cucumis, Fabricius
  - Bolina alata, Agassiz.
  - Mnemiopsis leidyi, Agassiz.
  - Pleurobrachia pileus (Fabricius).

ANNULATA AND VERMES

The free-swimming annelids may be grouped under three headings—true pelagic adults, benthonic adults swimming during their breeding season, and the early larval stages of all marine Polychæta. A fourth group may be added in this case to include the bottom forms carried by strong currents during storms.

Of the true pelagic annelids only one species occurs frequently in the waters of Buzzards Bay and Vineyard Sound, although Moore (1903) has described two other types from this region. *Tomopteros helgolandica* is taken from December to April at Woods Hole. During seasons when southerly winds are prevalent they have been taken in considerable abundance. The greatest number recorded was in 1906, when many specimens were taken almost daily throughout April until May 2. During the spring of 1923 there were almost no winds from the south, and as a result oceanic forms have been rare. One specimen of Tomopteros appeared on February 5, that being the only specimen taken during the year.

Benthonic annelids often appear at the surface in great numbers, particularly in the evening, during their breeding season. In the groups where the sexual products are discharged directly into the water the active period is comparatively short, sometimes lasting less than a week. This occurs in the various species of the family Nereidæ. The adults swarm at certain definite places, usually along sandy beaches or protected harbors, and literally fill the water with cloudy masses of eggs and sperm.

From July 20 to 24, 1922, *Nereis limbata* swarmed in immense numbers at the surface in the eel pond. A few were noticed at other spots along the shore, but none appeared in the daily surface collections. On April 1, 1923, the beach at Nobska Point was the scene of a swarming of *N. virens.* On many occasions during the first two weeks of April ripe males were seen swimming among the Fucus about the Fisheries dock. In this case, as in the case of *N. limbata*, free-swimming larvæ appeared in great numbers in the tow, but few adults were taken. The usual swarming season for *N. limbata* ranges from June to September. A few adults of *N. pelagica* were taken during the year, but none of these contained ripe sex products. The breeding season of this species is in August and September. *Platynereis megalops* is also commonly taken at the surface from July to September. Although the young were taken on several occasions, but one adult appeared in the collections of the past two summers. All of the members of this family undergo extensive physical changes in adapting themselves for pelagic life during the breeding period. The anterior, nonsexual part remains the same, but in the posterior, sexual region the parapoda become broad and flat and the chætæ increase greatly in length. In this form the worm is known as Heteronereis and is able to swim very rapidly.

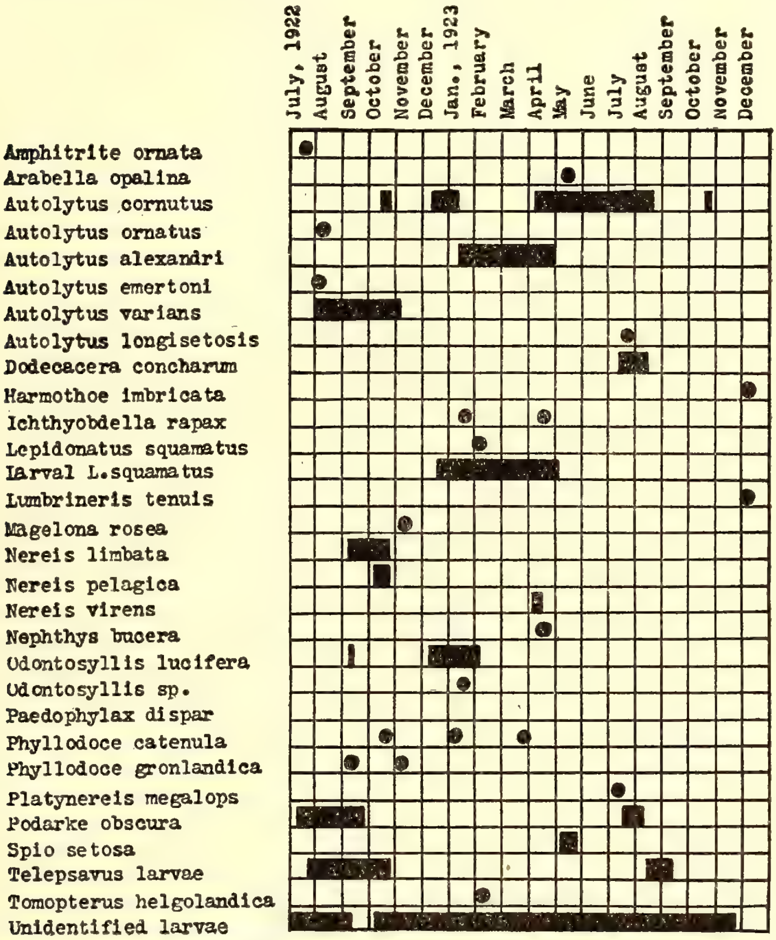

FIG. 33.—Occasional occurrence of annelids in surface collections from June, 1922, to May, 1923.
●, single specimen taken

In contrast to the Nereidæ stand the families Syllidæ and Hesionidæ. The different species of Autolytus carry their eggs and swim about for varying lengths of time, often occurring for periods of more than four months. For the greater part of the year they remain attached to hydroids and algæ on rocks and piles as nonsexual individuals. In this form they are not free-swimming and their occasional appearance in surface collections is accidental. In the breeding season certain of these nonsexual individuals develop eggs in the posterior part of the body (posterior to the gizzard), while others develop sperm. Strobilization then occurs, and sexual individuals, which immediately become pelagic, are broken off. The females that break off carry clusters of eggs in a pouch on the ventral side. The stolons are either male or female, the two sexes never developing from the same stalk. Occasionally chains of five or six worms, which have not yet separated, may be seen at the surface. Free-swimming males and male chains are usually more abundant than the females. Alexander Agassiz fully described this alteration of generations in 1862. The sexual species of Autolytus are highly phosphorescent and are often extremely numerous in the tow.

Podarke obscura is a very characteristic member of all evening surface collections of the summer. On calm, dark nights swarms of them appear at the surface in protected harbors. The first specimen taken in 1922 appeared on July 6, the last on September 27. In the strong currents about the collecting station the occurrence of Podarke was more scattering than is usual, although many were carried into the nets during both day and night. In daylight, however, the number was much smaller, because at that time the adults seek protection under rocks and among the Fucus.

Larvel annelids appear in the plankton at all seasons of the year. During the early spring they form almost the only representatives of the benthos in the tow. A very small percentage of the species has been worked out, and for that reason it has been impossible to identify a large number of the larval forms that were taken during the past year. Larval Nereis were very abundant during April and May in 1899, 1900, and 1923. These spring forms probably were *Nereis virens*. Another large increase in the latter part of October in each of the years recorded may have been *N. limbata*, although the date is rather late for this species. Such conclusions must remain as mere speculation until further data on the breeding seasons can be obtained. This can readily be realized if one considers that there are six species of the family Nereidæ represented at Woods Hole, and larval Nereidiformia have been taken in every month of the year except September.

Two very characteristic larval annelids appear each year in large numbers. The first occurs in late July and continues throughout October. Fewkes has described it from Newport as a species of the genus Telepsavus. His identification is doubtful, however, for no adult of the species has been recorded from this section of the Atlantic coast. In 1922 it appeared first on July 26 and continued to be taken until October 25. The second larvæ (*Lepidonatus squamatus*) appeared first on December 19. Throughout the spring it was taken daily in large numbers. The season lasted until the last of April. This fact is rather unusual for Sumner records the breeding season as late April, May, and June. An adult female of this species taken on February 2, 1923, was filled with ripe eggs. During May and June, 1922, no larvæ appeared in the surface collections. From these observations the breeding season is seen to be much more extended than has hitherto been supposed.

Occasionally postlarval forms occur after northeast storms. As these are not true free-swimming larvæ they are listed with adults taken under similar conditions. During the past year several nonplanktonic annelids have been taken. Certain of these may swim freely in their breeding season, but the occurrence in the collections was so scattering that I have not considered it as normal. *Dodecacera concharum* offers a peculiar problem. Scattered specimens, often quite numerous, varying from 15 to 20 mm. in length, appeared from July 16 to August 15, 1923. The presence of these immature specimens over such an extended period of time could hardly have been accidental, and yet Dodecacera is known to be a truly benthonic annelid.

Comparatively few leeches have been taken from the Woods Hole region. Sumner records five species, all of which were taken from fish. One species (*Ichthyobdella rapax*) appeared twice in the surface collections of 1922–23—once on January 20 and once on April 7. Both occurrences were during the breeding season of the winter flounder (*Pseudopleuronectes americanus*). Former records give the summer flounder as its host, but it is highly probable that it will be found on both species.

The following annelids were taken in 1922–23:

Amphitrite ornata (Leidy).
Arabella opalina (Verrill).
Autolytus cornutus, Agassiz.
A. ornatus, Verrill.
A. alexandri, Agassiz.
A. emertoni, Verrill.
A. varians, Verrill.
A. longisetosis, Agassiz.
Dodecacera concharum, Öersted.
Harmothöe imbricata, Malmgren.
Ichthyobdella rapax, Verrill.
Lepidonatus squamatus, Leach.
Lumbrineris tenuis, Verrill.
Magelona rosea, Moore.
Nereis limbata, Ehlers.
Nereis pelagica, Linnæus.
N. virens, Sars.
Nephthys bucera, Ehlers.
Odontosyllis lucifera, Verrill.
O. sp.
Pædophylax dispar, Webster.
Phyllodoce catenula, Verrill.
P. grönlandica, Öersted.
Platynereis megalops (Verrill).
Podarke obscura, Verrill.
Spio setosa, Verrill.
Telepsavus larvæ?
Tomopterus helgolandica, Greef.
Unidentified larvæ of several species.

Sagitta is the only true pelagic representative of the phylum Vermes found in this region. It usually appears in December and remains until June. In listing the Sagittæ of past years no attempt was made to distinguish between *Sagitta elegans* and *S. serrodentata.* The former is more littoral and northern in its distribution, while the latter is a southern oceanic form often occurring in the Gulf Stream. During the spring of the present year (1923) no specimens of *S. serrodentata* were taken. This may be explained by the fact that the prevailing winds have been from the north and comparatively few oceanic forms of any sort have found their way in. However, since *S. serrodentata* forms such an unimportant part of the outside plankton, its presence in the region of Woods Hole is, no doubt, so rare that the distribution curve of Sagitta for any year can be considered to be the seasonal variation of *S. elegans.* A sudden appearance after July and before November would probably follow a southwest wind, and in this case the species might be *S. serrodentata,* although deep-water collections off the coast in warm weather often reveal large numbers of *S. elegans.* Such a condition may have taken place in August 1903 (see fig. 35). On August 4, 1922, one specimen of *S. serrodentata* was taken and another on August 5.

In the 16 years that *S. elegans* has been recorded, with one or possibly two exceptions, none appeared before November or remained after July. The usual time of appearance is December. In 1899 a few were taken on December 23, and in 1898 many suddenly appeared on December 12. In 1922 two specimens were found on October 4, one on October 5, two on October 10, and gradually increased from then until early December, when large numbers appeared. The highest point is usually reached in February. During this month they swarm.

It is interesting to compare these results with those of Dr. H. B. Bigelow (1914) in Massachusetts Bay. In late December he found *S. elegans* in the tow. Throughout January and February the numbers increased until they formed the bulk of the plankton. Occasionally *S. serrodentata* was taken, but always *S. elegans* was by far the most abundant. When the water began to grow warmer in early March, the numbers fell off rapidly, so that on March 4 only 12 specimens were taken. The last Sagittæ appeared on April 14. This is merely additional evidence of the similarity of plankton north and south of Cape Cod in winter.

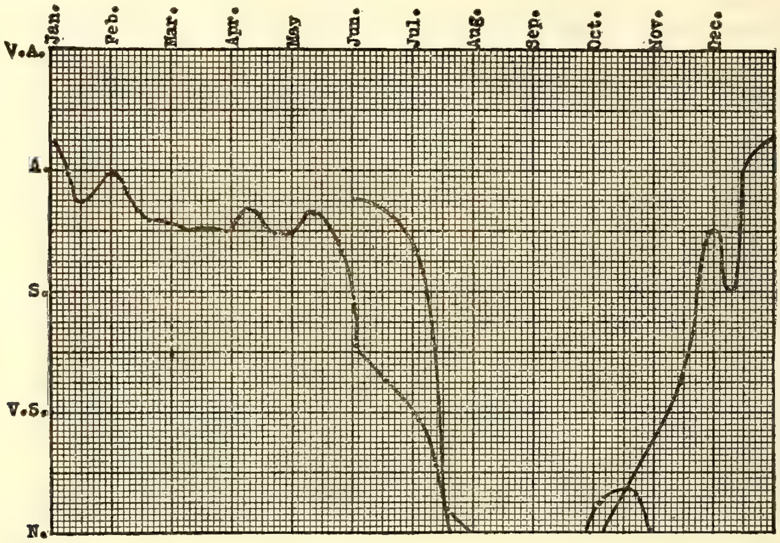

FIG. 34.—Occurrence of *Sagitta elegans* in surface collections from June, 1922, to December, 1923. ——, distribution in 1922; —.—, distribution in 1923

In March and April, 1923, swarms of *S. elegans* with ripe eggs were abundant in Great Harbor. During the latter part of April large numbers of eggs appeared and, together with the eggs of the mollusk *Littorina litorea,* made up the greater part of the tow. On May 2 the first young were observed. These increased rapidly in number and were very abundant throughout May and June. The last specimen was taken on July 18, although the numbers had been very small since June 20. In August, 1923, large numbers of small Sagittæ of the spring brood were taken off No Man's Land in deep water.

Many species of Platyhelminthes and Nemathelminthes have been recorded from surface collections, but these have been accidental in occurrence and, with the exception of certain early larvæ, do not form a part of the littoral plankton. Most members of the phylum, excluding internal parasites, live among the marine plants and detritus on muddy bottoms or on piles. Some forms like the rotifers, of which a few marine genera occur at Woods Hole, swim about freely, but even these are not a part of the open-water plankton. Only one rotifer (*Synchæta triopthalma* Lauterborn) was observed during the past year, and this was seen but once.

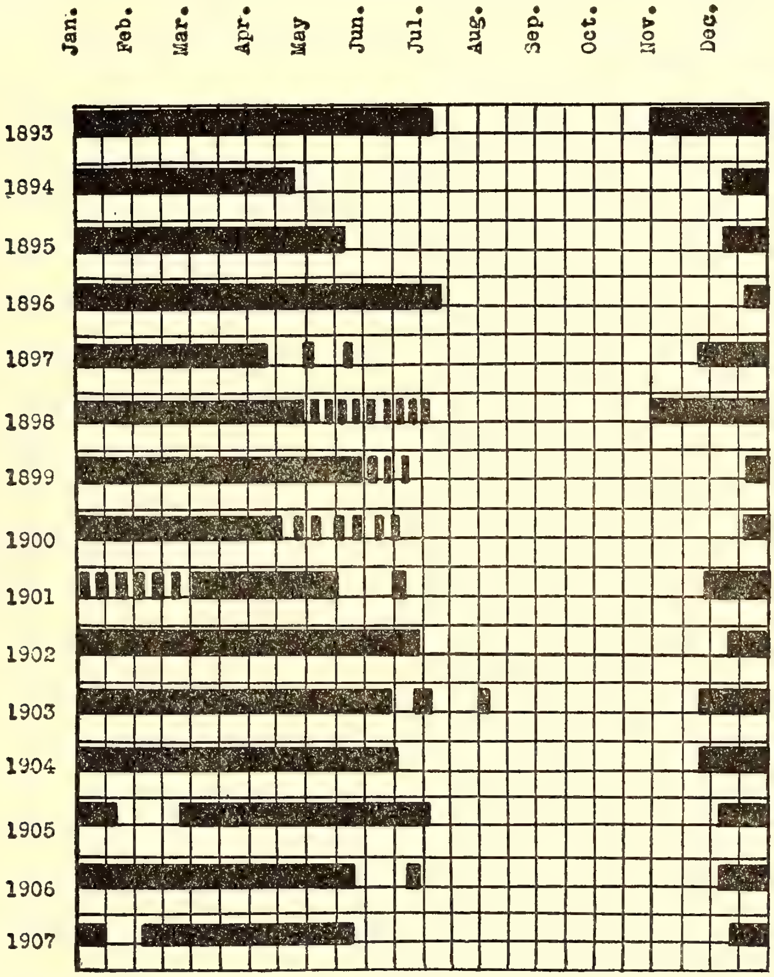

FIG. 35.—Occurrence of *Sagitta elegans* in surface collections during successive years. Broken lines indicate scattering occurrence

Often in summer planarians appeared, but no attempt was made to identify them. One species, however (*Microstomum davenporti* Graff), was taken in the harbor on two occasions, August 5 and 16, and in the Sound on August 18 and September 21. A single specimen of *Nectonema agile* Verrill was found among much detritus after a hard wind on July 11.

MOLLUSCA

Gastropod larvæ are found throughout the year in all surface collections from inshore waters. There is considerable doubt as to the percentage of forms whose early stages are free-swimming. Many species, such as *Busycon canaliculatum* (Say) and *Buccinum undatum* Linnæus, secrete cases in which the young pass their early stages, emerging in the form of the adults. Others deposit eggs in jelly-like masses attached to the underside of rocks and on marine plants. *Littorina palliata* (Say) is an example of this type. Still other forms, such as *L. rudis* Maton, are viviparous. The eggs of all of these are never found floating, and the young normally do not appear in the plankton. Certain young after emerging from the egg cases may accidentally be carried along by the currents. This probably explains the presence of many species taken during the summer and fall.

A fourth group of gastropods no doubt contribute the bulk of the planktonic larvæ. This group, of which *Littorina litorea* and *Lacuna vincta* are examples, discharge their eggs directly into the sea water. In these two species each egg is especially adapted for floating by a surrounding ring of jelly, which gives the appearance of the trench helmets worn by the American soldiers in the late war. This device serves also as a means of protection. The eggs and free-swimming larvæ are found in great numbers from March until July. This is also the breeding season of *Littorina litorea* in English waters, according to Tattersall, who made extended observations upon that species. *Lacuna vincta* also swarms in February and March, some eggs having been found as early as December by Sumner. The eggs of this species may be distinguished by a light greenish tinge. In March of the present year (1923) great numbers of Littorina eggs appeared daily and increased throughout April. None were found in collections of the previous June. There was a maximum of eggs identical to those of Littorina in the fall, which the author has not been able to identify. There can be little doubt that this floating condition explains the rapid expansion of *Littorina litorea* after it was once established on the western Atlantic coast.

An interesting adaptation to pelagic existence is found in a larval vitrinellid, the species of which I have been unable to ascertain. Shortly after the nucleus has formed, a broad shield grows out as an extension of the shell. This shield appears like the wide brim of a straw hat and enables the larva to float. Later, as older specimens showed, the shield is lost and the young mollusk sinks to the bottom. It is an interesting adaptation and has never before, to my knowledge, been noted.

In the summer of 1922 Dr. Paul Bartsch kindly aided me in identifying the gastropod larvæ that appeared during June, July, and August. The many forms often bear no resemblance to the adults, but are identified by comparing the nuclear whorls. These never change and offer an excellent means of identification. The nucleus is now used as a basis for classification among adult mollusks also.

Apparently none of the larger gastropods have free-swimming stages, the bulk of the summer forms coming from those minute species that live on the floating Fucus and Sargassum. The following gastropods were distinguished in surface collections of 1922:

Littorina litorea (Linnæus).
Bittium alternatum, Say.
Astyris lunata (Say).
Skenea planorbis, Fabricius.
A combellid, probably Anachis avara (Say).
Tritonofusus stimpsoni (Morch).
Triphoris nigrocinctus, Stimpson.
Lacuna vincta, Montagu.
A vitrinellid genus (?).

But one Nudibranch mollusk has been recorded by Edwards from surface collections. This species (*Facelina bostoniensis* (Couthouy)) appears each spring, often in large numbers. This year it appeared on January 21 and continued to be taken until May. Upon examination many females were found to contain dozens of small larvæ, which were very similar in form to the adults. Four other species were represented by single specimens taken during the year—*Elysiella catula* (Agassiz), June 1; *Doto coronata* (Gmelin), September 6; *Alderia harvardiensis* (Agassiz), March 29; and family Dotonidæ, November 8.

Clione limacina (Phipps), a pteropod, is often taken in large numbers around Marthas Vineyard. It is a member of the oceanic plankton and is occasionally blown into Great Harbor during southern storms. The author has five records of its appearance in surface collections. The first four—September 10, 1888, March 20, 1896, April 28, 1911, and May 2, 1911—were taken by V. N. Edwards; the fifth, on May 3, 1918, by R. A. Goffin. Another pteropod (*Heterofusus retroversus* (Fleming)) had been recorded once in local waters (Sumner, 1913a). A single specimen was taken in Great Harbor on January 12, 1924.

The larval Pelecepoda present a most difficult problem to the plankton investigator. The early larvæ all look alike and can be distinguished, with any degree of certainty, only by careful measurements. During the summer the author was able to make few such measurements and for that reason the results are very incomplete. The late larval stages are more easily distinguished. J. Stafford's excellent paper on bivalve larvæ made the identification of these forms a rather simple matter. At this stage, however, the bivalves sink to the bottom and are taken in much smaller numbers.

The most common pelecepods of this region live in the shallow waters of protected bays and harbors. For that reason they are quickly affected by the increase in temperature during the spring. The length of time required for the ripening of the gonads is not known, but many larvæ of *Mytilus edulis* were found early in June, 1922. Later in July larvæ of a slightly different shape were noted. These proved to be the young of both *Venus mercenaria* and *Mya arenaria*. Many Pecten larvæ were taken near Block Island in September, but none appeared at Woods Hole. Mya, Venus, and Mytilus remained throughout the summer and until late in the fall. By August 10 Mytilus had almost acquired the adult shape and appeared less frequently in the collections, although many were taken throughout November and December. By this time the larvæ had long since passed the swimming stage and were carried into the nets by the strong currents. No oyster larvæ were noted during the summer of 1922.

Of the Amphineura one species (*Chætopleura apiculata* Carpenter) was taken on September 23, 1922. The larva was at that time in a late stage of development, the shell measuring 1.2 mm. in length. However, the free-swimming period had not ceased, for the little animal continued to float about in a watch glass for several hours.

Throughout the latter part of May and June the eggs of *Loligo pealii* Le Sueur are found in great abundance. Scattering young forms appeared on June 2, 1922, and increased rapidly until July 11, when the largest number was taken. On clear, calm days small schools of these little cephalopods could be seen swimming at the surface in much the same manner as the adults. Such schools were particularly common about the fish traps, where large numbers of adults are frequently captured. In August there was a decrease in the abundance. This continued throughout that month and early September. Two specimens were taken in October and one on November 20. The last occurrence is rather surprising, because no young forms had been seen since October 18, and then only one specimen was found. In 1899 the last specimen was taken on October 24. In 1923 the season lasted from June 26 until October 16 (fig. 36).

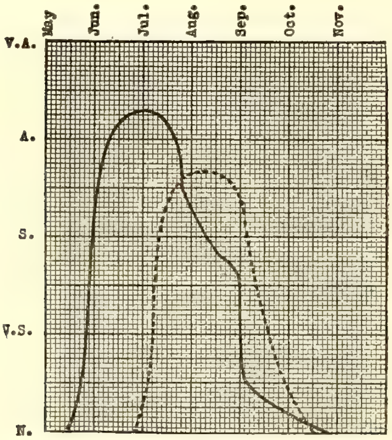

FIG. 36.—Occurrence of larval forms of *Loligo pealii* in surface collections of 1922 and 1923. ———, distribution in 1922; -------, distribution in 1923

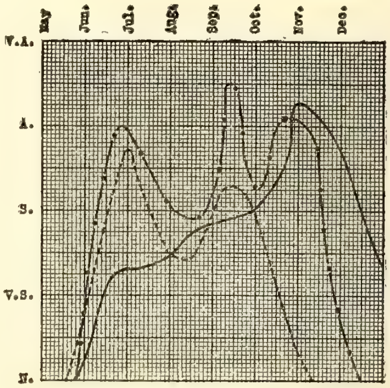

FIG. 37.—Occurrence of Phyllopoda in surface collections from May to December, 1922. —.—, *Podon intermedius;* ———, *Evadne nordmanni;* --------, *E. tergestina*

ECHINODERMATA

Practically all of the echinoderms of the Woods Hole region have a free-swimming stage. A few holothurians and one starfish (*Henricia sanguino lenta* (Müller)), are viviparous, but these are uncommon forms. In certain years great numbers of the larvæ of Asterias have been taken in surface towings. None were found in collections of 1898–99 nor during 1922, although Asterias is known to breed throughout the summer months in this region. In 1923 a single brachiolaria of Asterias appeared on July 16, it being the only specimen taken that year. In Narragansett Bay the season is usually completed in a few weeks in late June; after that hardly a ripe adult can be found. As four species of Asterias have been recorded from Woods Hole it is probable that all do not breed at the same time. This might account for the extended breeding season.

A specimen of *Leptosynapta inhærens* (Müller), 20 mm. long, was taken on September 19 after a hard northeast storm. This was not a free-swimming form and would not normally occur in surface collections.

CRUSTACEA

PHYLLOPODA

Two species of marine Phyllopoda (*Podon leuckarti* and *Evadne nordmanni*) have been recorded from the Atlantic coast of the United States. D. L. MacDonald records three species from St. Andrews, New Brunswick, two of which (*E. spinifera* Müller and *Podon finmarchichus*) have never since been taken. As the name of the original describer does not appear on the list, I am unable to find any other record of *P. finmarchichus*. This name is not given in any available literature on the subject. *E. spinifera* is a southern form that has not appeared in this region during the past year.

Two species of Evadne were taken at Woods Hole in abundance during the summer of 1922. *Evadne tergestina,* new to this region, appeared on May 20, becoming very numerous by July 1. During the summer diatom maximum the numbers decreased but rose again in September. After that they declined until November, the last being recorded on November 15.

Evadne nordmanni appeared shortly after *E. tergestina,* but never became abundant in the summer months (fig. 37, p. 138). In October they increased and reached their highest point about November 1, at a time when *E. tergestina* was fast disappearing. Throughout December they declined rapidly and disappeared about January 20. *E. nordmanni* is easily distinguished by its pinkish color as well as its different appendage formula. *E. tergestina* is usually quite colorless and very transparent.

Podon intermedius was first recorded from the western Atlantic by MacDonald at St. Andrews, New Brunswick. This species appeared in the surface collections of Great Harbor on May 27, 1922, and increased rapidly, reaching a high point in the last week of June. The numbers declined during the period of the diatom swarms, but rose again, reaching the peak in the middle of September. Another diatom maximum in early October reduced the number a second time, but they once more rose and remained until the last of the month. During November *P. intermedius* became scarcer and disappeared about December 15. In general, the season is the same for the various species. *Evadne nordmanni* has the longest occurrence. The distribution of *P. intermedius* in 1923 was very similar to that of the previous year, except that it arrived later (fig. 38).

No specimens of *Podon leuckarti* (Sars) were taken during the past year, and a careful search through the collection of 1899 and 1900 failed to show any, although

Pratt and Sharpe recorded them as occurring in great abundance. No specimens have been placed in the National Museum, and as Sharpe's collections were lost I have been unable to find any identified material. It seems strange, however, that a species not recorded from the region appeared in such great abundance, while the common form was absent during those three years.

On July 28, 1923, *Podon polyphemoides* appeared in the surface tow. No specimens of this species had been observed in the collections of the previous year or in 1899 to 1900. The season was very short, lasting less than four weeks. The last specimen was taken on August 22. At the mouth of New Haven Harbor in Long Island Sound, August 1 to 3, 1923, swarms of this species were observed. They were so numerous that a surface tow of 15 minutes yielded 80 c. c. of *P. polyphemoides* and almost nothing else.

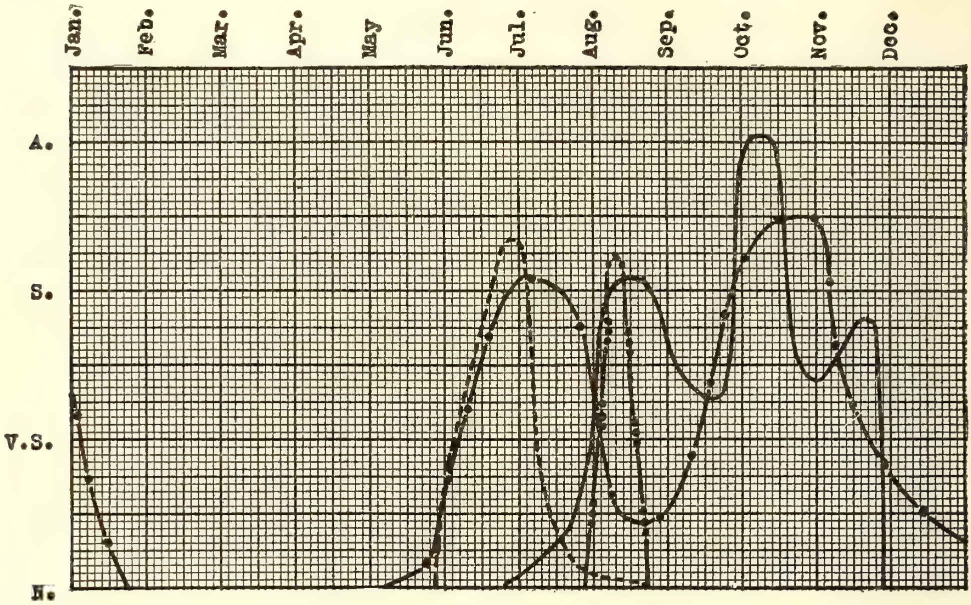

FIG. 38.—Occurrence of Phyllopoda in surface collections of 1923. ——, *Podon intermedius;* —. . . —, *P. polyphemoides;* —.—, *Evadne nordmanni;* --------, *E. tergestina*

The following phyllopods appeared in the surface collections of 1922–23: *Podon intermedius* Lilljeborg, *P. polyphemoides* (Leuckart), *Evadne nordmanni* Loven, and *E. tergestina* Claus.

OSTRACODA

With few exceptions the ostracods are not true planktonic animals. None of the Woods Hole species belong in the pelagic group, although many appear in surface collections after storms or hard winds, along with particles of sand, Foraminifera, and other bottom forms.

Cushman found that, excepting one specimen, all species of the Myodocopa taken in the survey of Vineyard Sound and Buzzards Bay came from the "Gut of Canso," directly across the harbor from the fisheries station.

In the collections of the past year one of this tribe (*Cylindroleberis mariæ*) appeared with greater frequency than any other one species, even though the Podocopa are much more abundant at certain spots in Great Harbor. This instance shows how easily wrong conclusions may be made in the study of littoral plankton if the bottom fauna is not clearly understood. It illustrates, also, an important point about the fauna of the harbor. The bottom forms dwelling here are so distributed that they are protected from the rushing currents, although they are able to derive benefit from the food material carried by these waters. For that reason, even under unusual conditions, the benthos occurring in surface collections probably is transported from Buzzards Bay. This is quite evident in the case of amphipods where the distribution is very well understood. Even the animals of the "Gut of Canso" are carried away rarely, and the ostracods become dislodged only when the hydroids and Fucus, to which they attach themselves, are torn from their bases.

The following ostracods were taken in 1922–23: *Sarsiella americana* Cushman, *Cylindroleberis mariæ* (Baird), *C. zostericola* Cushman, *Loxoconcha impressa* (Baird), *Cythereis emarginata* Sars, and genus Cythereis (several species).

COPEPODA

Together with the Phyllopoda and an occasional euphausid or hyperid, the Copepoda form the only truly pelagic Crustacea of the local plankton. Except in the seasons of diatom maxima, they are always present in abundance. Farran found that whenever a species is present in sufficient numbers a distinct periodicity in its occurrence is noticeable. This is true at Woods Hole. Although copepods are always present in varying numbers, certain species are continually disappearing and being replaced by others. The copepods of Great Harbor may be divided roughly into two great groups—the summer community and the winter community.

The summer forms may arise from three sources: (*a*) Annual appearance of local coastal species common to the region, (*b*) the young of these common forms, appearing often in large numbers during the breeding season, (*c*) southern oceanic forms blown in by winds from the Gulf Stream during the warm weather.

The first of these sources accounts for most of the summer species. These may again be grouped under two headings: (1) True pelagic species and (2) bottom forms appearing after hard winds. The most typical summer pelagic species are *Acartia tonsa* and *Centropages typicus*. These form the bulk of the summer copepod fauna. Later in the fall *Pseudodiaptomus coronatus* reaches its maximum and outnumbers all other forms. This, however, is not a true summer species, but serves as a connection between the warm and cold water copepods. *Tortanus discaudata* serves in a similar capacity in the spring and early summer. Benthonic adults of the family Harpacticidæ are often taken in surface collections. These are usually found among bottom plants and algæ but are capable of swimming quite as well as the Gymnoplea. The most common summer Copepoda are *Acartia tonsa*, *Centropages typicus*, *Pseudodiaptomus coronatus*, *Labidocera æstiva*, *Oithona similis*, *O. brevicornis*, *Alteutha depressa*, *Parategastes sphæricus*, *Amphiascus obscurus*, *Ilyopsyllus sarsi*, and *Dactylopusia vulgaris*.

The young of the summer copepods never appear in large numbers, as in the case of winter breeders, and only three species—*Acartia tonsa*, *Pseudodiaptomus coronatus*, and *Centropages typicus*—were identified.

The third summer group varies considerably in different seasons. If the prevailing winds through June, July, and August are from the south, great numbers of Gulf Stream forms may appear. Such was the case in 1922, and for that reason several species new to this coast were taken. The common annual visitors also appeared in abundance. The southerly winds did not continue in the fall, however, and the result was that the usual tropical fish and cœlenterates were not observed at Katama Bay and in Vineyard Sound. No doubt these conditionsa ffected copepods as well. As an illustration of this *Microsetella rosea* appeared in great numbers on September 2 in vertical hauls taken off Block Island. Later during this month (fig. 46, p. 145) scattering specimens were observed at Woods Hole. Much larger numbers would probably have been found here if hard south winds had

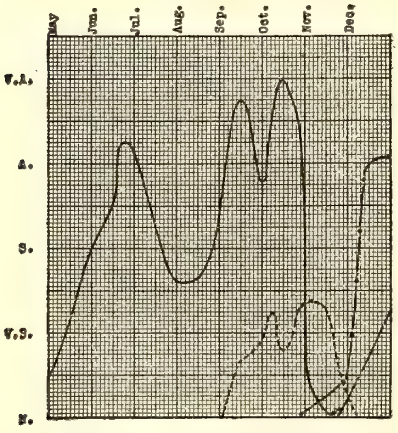

FIG. 39.—Occurrence of species of Acartia in surface collections from June to December, 1922. ——, *Acartia tonsa;* - - - - - -, immature *A. tonsa;* — — —, *A. bifilosa;* —•—, *A. clausii*

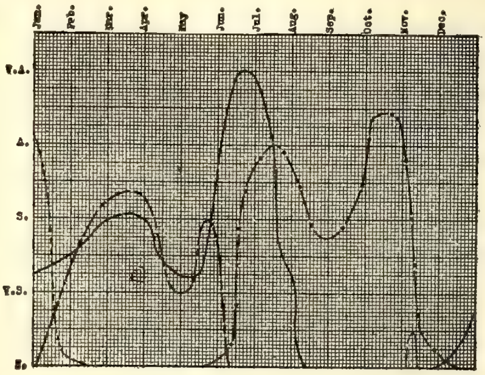

FIG. 40.—Occurrence of species of Acartia in surface collections of 1923. —•—, *Acartia tonsa;* ——, *A. bifilosa;* - - - - - - -, *A. clausii;* — — —, *A. longiremus*

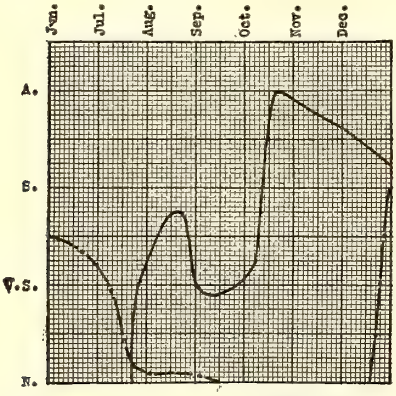

FIG. 41.—Occurrence of *Pseudodiaptomus coronatus* and *Tortanus discaudata* in surface collections from June to December, 1922. ——, *P. coronatus;* —•—, *T. discaudata*

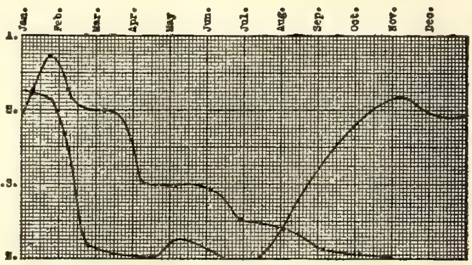

FIG. 42.—Occurrence of *Pseudodiaptomus coronatus* and *Tortanus discaudata* in surface collections of 1923. —— *P. coronatus;* —•—, *T. discaudata.*

prevailed. The summer forms from the Gulf Stream taken in 1922–23 were *Pontella pennata, P. meadii, Anomalocera patersoni, Microsetella rosea, Setella gracilis,* and *Thaumaleus claparedii.*

No distinct division can be made dividing the summer forms from the winter ones. Figures 40, 42, 44, etc., show clearly how much the seasonal distributions of the various species overlap each other. Certain forms, such as *Centropages hematus,* appear as early as August and remain until May. As the breeding season is in December and January, they are considered to be true cold-water forms.

The winter copepods may roughly be divided into four groups: (*a*) Those northern species that remain in deep water or north of Cape Cod during the summer, entering this region every winter in great numbers, (*b*) the young of the winter species, (*c*) northern oceanic forms occasionally finding their way in, (*d*) Harpacticidæ, usually accidental members of the plankton, but in a few cases rising to the surface during the breeding season.

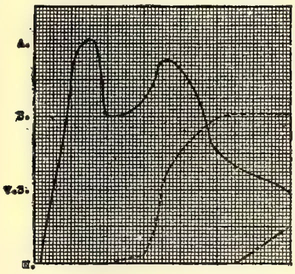

FIG. 43.—Occurrence of Centropages in surface collections from June to December, 1922. ———, *Centropages typicus;* - - - - -, *C. hematus;* —•—, *C. hematus* (immature forms)

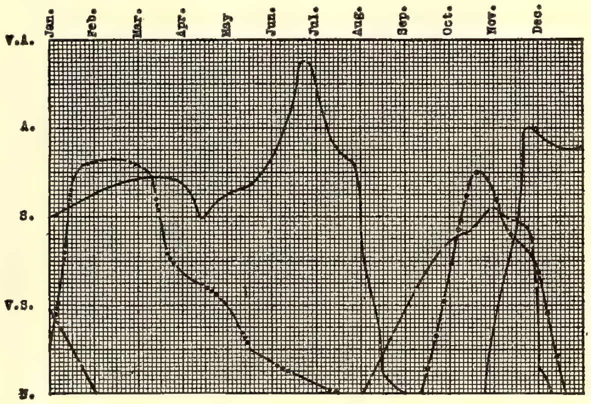

FIG. 44.—Occurrence of Centropages in surface collections of 1923. — — —, *Centropages typicus;* ———, *C. hematus;* —•••—, *C. typicus* (immature form); —•—, *C. hematus* (immature form)

Three copepods are usually characteristic of all winter plankton—*Pseudocalanus elongatus, Temora longicornis,* and *Centropages hematus.* During the years 1922 and 1923 almost no specimens of Temora appeared. This is very unusual, for all samples of past years taken at this season are literally filled with them. As they appear in the greatest numbers in February, March, and April, the unusually cold weather of the spring of 1923 (fig. 5, opp. p. 100) may have affected them as it has many of the other animals. The young of Pseudocalanus and Centropages became so abundant in January and February that they far outnumbered the adults, a condition which was never found among summer forms. A few immature Temora were noted, but their appearance was not common.

Northern species are sometimes plentiful in the waters of Vineyard Sound and often appear in surface collections in Great Harbor. *Calanus finmarchicus* is the most common of these cold-water forms. *Metridia lucens, Eurytemora herdmani,* and *E. hirundoides* were taken often during the spring of 1924. No other northern copepods to my knowledge have ever been recorded from Woods Hole.

Members of the family Harpacticidæ sometimes appeared during the winter months. Only one species (*Tachidius brevicornis*) had a definite free-swimming period. Egg-bearing females were taken in towings throughout the spring, often in great abundance. This, apparently, was the only one of the group that had a pelagic period during the year. Others may have been free-swimming but did not occur in sufficiently large numbers to indicate it.

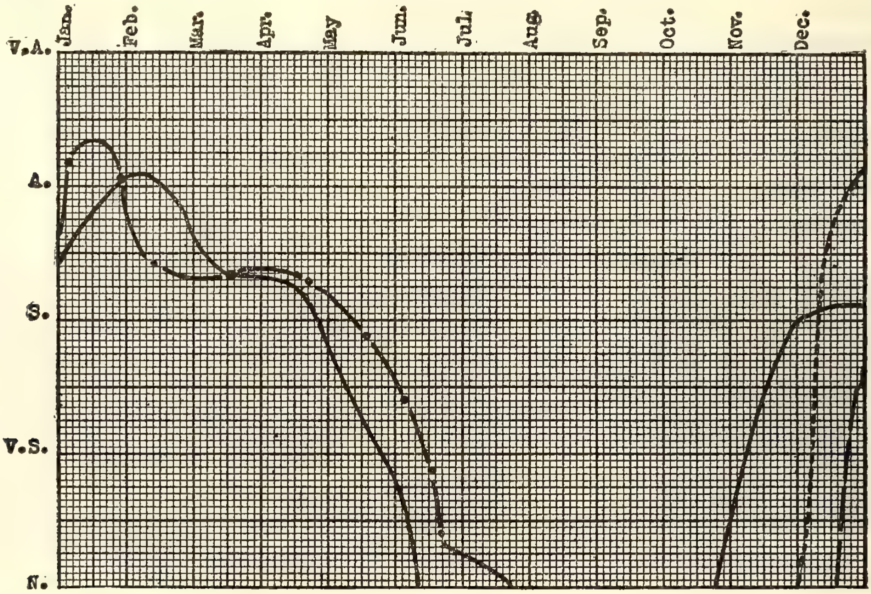

FIG. 45.—Occurrence of *Pseudocalanus elongatus* in surface collections from June, 1922, to December, 1923. ----, distribution of adults in 1922; — — —, distribution of immature specimens in 1922; ——, distribution of adults in 1923; —.—, distribution of immature specimens in 1923

The winter forms collected during the past year were as follows:

Pseudocalanus elongatus.
Calanus finmarchicus.
Centropages hematus.
Temora longicornis
Eurytemora herdmani.
E. hirundoides.
Metridia lucens.
Acartia clausii.
A. longiremus.
A. bifilosa.
Tortanus discaudata.
Microsetella norvegica.
Idya furcata.
Tachidius brevicornis.

Over 50 species of parasitic copepods have been recorded from Woods Hole. Often they are taken in surface collections, but they do not normally form a part of the plankton except in their larval stages. None appeared in 1922. In 1923 a male *Caligus schistonyx* was taken.

Three lists of free-swimming copepods have been made for this region. Wheeler recorded 30 species, but most of these were taken in the vicinity of the Gulf Stream and are extralimital. Sharpe recorded 60 species in 1911, of which only 23 occurred at Woods Hole. Twelve others were quoted from Williams's report on Narragansett Bay, and the remainder were taken from Wheeler's list. Sumner, in 1911, compiled 25 (plus 1?) species from the combined data of Wheeler and Sharpe, no new additions being made.

During the past year 42 species of free-swimming copepods appeared in the surface collections taken from the end of the Fisheries dock. Of these, 19 belong to the tribe Gymnoplea and 22 to the tribe Podoplea. In Sharpe's list 12 species from this region belong to the Gymnoplea. The list for this tribe. I believe, is now fairly complete. The Podoplea, however, have scarcely been touched and will, no doubt, yield many more species when carefully studied. Twelve species taken in 1922–23 are new to the Woods Hole region. I have not listed as new any forms previously recorded from Narragansett Bay.

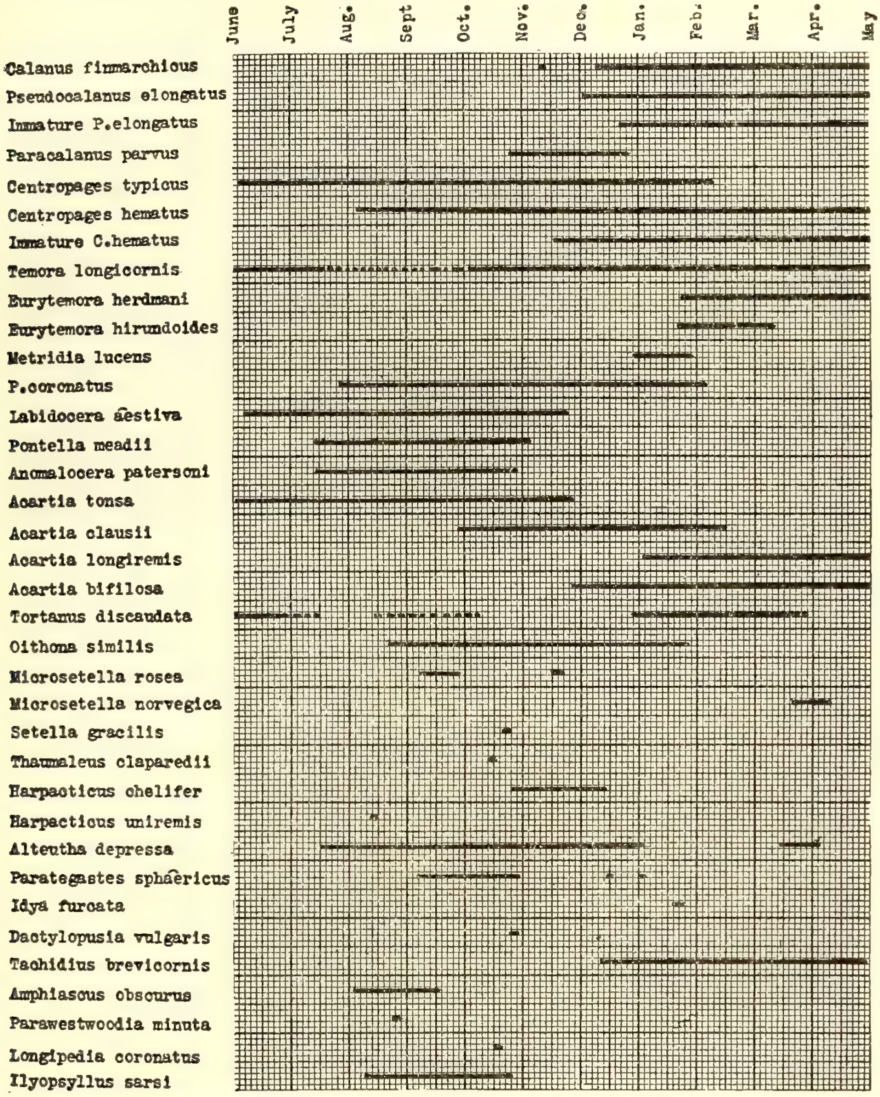

FIG. 46.—Occurrence of Copepoda in surface collections from June, 1922, to May, 1923. (*Oithona brevicornis* is not distinguished from *O. similis*)

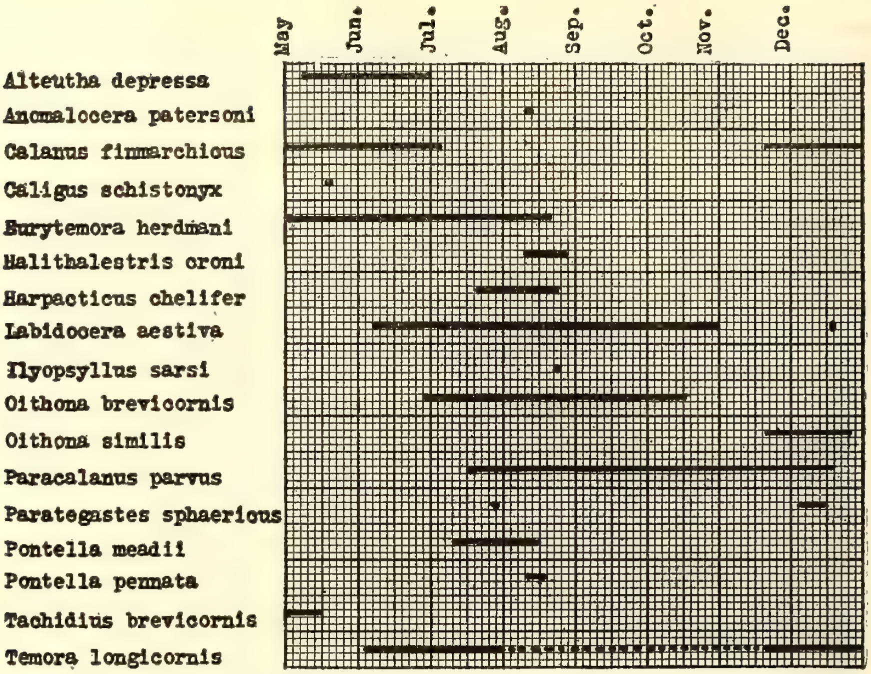

FIG. 47.—Occurrence of certain copepods in surface collections from May to December, 1923

The following Copepoda were taken during 1922–23:

Tribe GYMNOPLEA

Family Calanidæ:
- Calanus finmarchicus (Gunnerus).
- Pseudocalanus elongatus (Bœck).
- Paracalanus parvus, Claus.[1]

Family Centropagidæ:
- Centropages typicus, Kröyer.
- C. hematus (Lilljeborg).
- Temora longicornis (Müller).
- Eurytemora herdmani, Thompson and Scott.
- E. hirundoides (Nordquist).
- Metridia lucens, Bœck.
- Pseudodiaptomus coronatus, Williams.

Family Pontellidæ:
- Labidocera æstiva, Wheeler.
- Pontella meadii, Wheeler.
- P. pennata, Wilson.[1]
- Anomalocera patersoni, Templeton.
- Acartia tonsa, Dana.
- A. longiremis (Lilljeborg).[1]
- A. bifilosa, Giesbrecht.[1]
- Tortanus discaudata (Thompson and Scott).
- Acartia clausii, Giesbrecht.

Tribe PODOPLEA

Family Cyclopidæ:
- Oithona similis, Claus.
- O. brevicornis, Giesbrecht.[1]
- Hermanella sp.

Family Harpacticidæ:
- Microsetella rosea, Dana.[1]
- M. norvegica, Bœck.
- Setella gracilis, Dana.[1]
- Thaumaleus claparedii.[1]
- Harpacticus chelifer (Müller).
- Alteutha depressa, Baird.
- Harpacticus uniremis, Kröyer.
- Parategastes spæricus (Claus).
- Idya furcata (Baird).
- Dactylopusia vulgaris, Sars.
- Laophonte sp. A.[2]
- L. sp. B.[2]
- Tachidius brevicornis (Müller).
- Amphiascus obscurus, Sars.[1]
- Parawestwoodia minuta, Claus.[1]
- Longipedia coronata, Claus.
- Ilyopsyllus sarsi, Sharpe.
- Asellopsis sp.
- Halithalestris croni (Kröyer).

Family Caligidæ: Caligus schistonyx, Wilson.

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[1] New to Woods Hole.

[2] Both differing distinctively from *L. longicaudata* Bœck. New to Woods Hole.

CIRRIPEDIA

At certain seasons of the year barnacle larvæ are very abundant in the plankton. In both the nauplius and "cypris" stages they swim freely, although as a rule the "cyprids" settle on the Fucus soon after the metamorphosis and are not taken in large numbers in surface collections. At such times often thousands can be taken in a single sweep of a hand net drawn through the Fucus near the water's edge. The nauplii of the three species of Balanus are so much alike that even the most careful identification is often rather uncertain. However, the difference in the breeding periods makes the identification easy in the field, although in certain years the seasons of *Balanus crenatus* and *B. eburneus* overlap.

Balanus crenatus is not as abundant in the immediate vicinity of Great Harbor as are the other species of the genus, and for that reason the larvæ occur in much smaller numbers in surface collections. The breeding season starts early in June and generally continues until the middle of July. In 1922 (fig. 48) the first larvæ appeared on July 2; the last on July 16. They were abundant on only one day—July 13. After this a single specimen was taken on July 15 and one on July 16. It is possible that nauplii may have occurred after August 1, when fairly large numbers of *B. eburneus* suddenly appeared. However, as an interval of 15 days elapsed between the two periods, the possibility of a stray *B. crenatus* nauplius being present would probably be so small that it need not be considered. In 1923 the first specimen appeared on June 29 (fig. 49). Scattered nauplii and "cyprids" were taken until July 23. Off Coney Island, N. Y., swarms of early nauplii (no doubt *B. crenatus*) were taken on June 12, 1923.

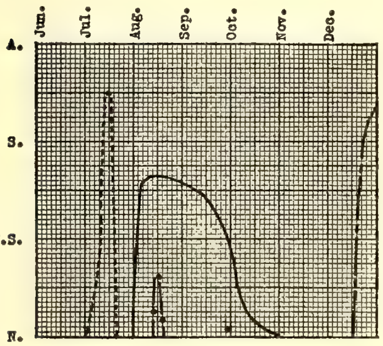

FIG. 48.—Occurrence of barnacle larvæ in surface collections from June to December, 1922. — — —, *Balanus balanoides*; - - - - - -, *B. crenatus*; —•—, *Chthamalus stellatus*; ———, *B. eburneus*; +, Lepas sp.

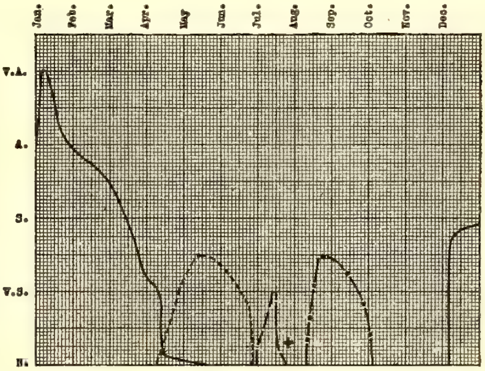

FIG. 49.—Occurrence of barnacle larvæ in surface collections of 1923. ———, *Balanus balanoides* nauplii; - - - - - -, *B. balanoides* "cyprids"; — — —, *B. crenatus*; —•—, *B. eburneus*; +, *Chthamalus stellatus*

Balanus eburneus is usually found in August, although the nauplii seldom form an important part of the surface collections. This may be due to the fact that the summer plankton is particularly rich and the barnacles, therefore, are greatly outnumbered. It is certain, however, that they never appear in such swarms as does *B. balanoides*. The first nauplii in 1922 (fig. 48) appeared on August 1, scattering individuals being taken until November 12, when the last specimen was observed. In 1923 the first nauplii appeared on August 12 (fig. 49).

Balanus balanoides appeared first on December 16, 1922 (fig. 48). By January 1 great numbers filled the tow. An examination of adults at this time showed that almost every specimen was filled with young and all seemed to be at exactly the same stage of development. In 1923 the first nauplii appeared on December 7 (fig. 49). On February 8, 1923, the first "cypris larvæ" appeared. These were at all times far less abundant that the nauplii. Throughout February and March they continued to appear, declining in April, although a few specimens were found in every haul. In certain parts of Long Island Sound, on March 5 and 6, the "cypris larvæ" were exceedingly abundant. The season in 1899 and 1900 coincided exactly with that of 1922 and 1923.

A comparison of this locality with other places along the coast is necessary in order to understand the relative position of Woods Hole. In Massachusetts Bay Bigelow found nauplii of *Balanus balanoides* throughout March and early April, 1913. Nauplii swarmed off Boon Island on April 5 of the same year. By April 9 large numbers of the "cyprids" with few nauplii were observed, while collections of seven days later revealed only "cyprids." These were most numerous from April 25 to 30, when they formed the bulk of the macroplankton, and continued to appear as scattered forms until the middle of May, when all had practically disappeared.

In early March swarms of Balanus were found in the "cypris stage" among the Fucus along the shores of upper Narragansett Bay. Some were already attached. In Newport Harbor the author found large numbers of nauplii from January 25 to 31, 1922. The largest swarm appeared on January 30. On March 4 of the same year "cyprids" literally filled the waters in the harbor of Bristol, R. I. It was not possible to carry on further observation in this locality, so the duration of the season was not determined. The author has taken nauplii in upper Narragansett Bay in large numbers in late January.

From these records it appears that the breeding season in Narragansett Bay and vicinity is somewhat later than at Woods Hole. This may be because the water responds more quickly to sudden drops in air temperature and retards the developing eggs. As one goes farther north the season grows later. Thus, Dr. Bigelow found that the breeding time starts in March in Massachusetts Bay and terminates quickly, due to the apparent rapid development of the larvæ. In Newfoundland the breeding season of this species is in June and July.

Chthamalus stellatus, although quite abundant locally, appeared in very small numbers in the plankton on only two days in 1922—August 15 and 16. No "cyprid larvæ" were found. In 1923 a single specimen was taken on July 23.

A single nauplius of Lepas appeared in the collections on September 30, 1922. This larva often occurs locally, although the adults are not real residents of the region but are blown in by southerly winds and often appear in great numbers on floating logs and Sargassum. During such seasons the larvæ of several species are frequently found.

ARTHROSTRACA

Twenty-seven species of Amphipoda were taken in surface hauls during the past year. But one of these (*Euthemisto bispinosa*), belongs to the pelagic family Hyperiidæ. Young specimens were found on five occasions in January. The adults, which are often parasitic in Aurelia and Cyanea, are usually seen after southerly winds, when the medusæ are blown into the harbor. All other amphipods belong to the benthos. During the breeding season, however, some species swim at the surface, both in daytime and at night, and are often taken in the tow in large numbers. Thus, the bottom forms may be divided into three groups, viz: (1) Those that swim during the breeding season, (2) those that are carried by the currents, and (3) those forms that for some reason other than the breeding season are attracted to the surface.

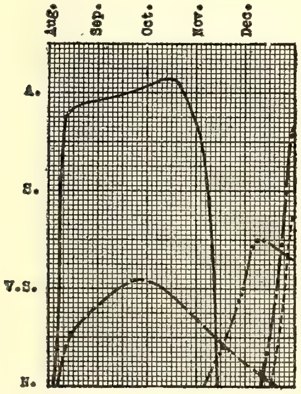

FIG. 50.—Occurrence of amphipods in surface collections from June to December, 1922. Free-swimming period during the breeding season. ——, *Batea secunda;* —‥‥—, *Monoculodes edwardsi;* —.—, *Gammarus annulatus;* -------, *Calliopius læviusculus;* —.—, *Stenothoë cypris*

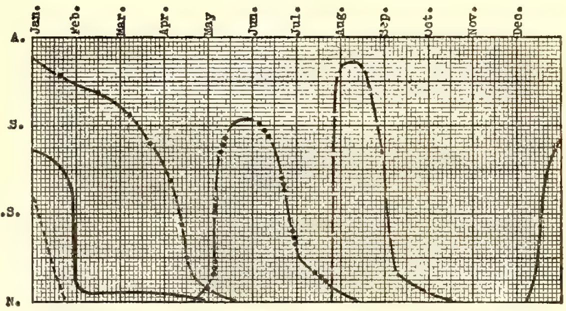

FIG. 51.—Occurrence of amphipods in surface collections of 1923. Free-swimming period during breeding season. ——, *Calliopius læviusculus;* —.:.—, *C. læviusculus* (young); --------, *Monoculodes edwardsi;* — — —, *Batea secunda;* —.—, *Gammarus annulatus*

In the first group there are two very conspicuous summer breeders. These can be found in Figure 52, designated by a long line. Certain forms, like Caprella, appear to have such a season, but this is caused by another condition. They live on hydroids, and as many of these are found floating after every strong wind the amphipods attached to them will float long after other forms have sunk again to the bottom. Of the summer forms *Batea secunda* and *Stenothoë cypris* are very noticeable. At times hundreds of specimens were taken in a single haul, many of the females carrying eggs or early embryos.

On November 6, 1922, *Monoculodes edwardsi* started breeding (fig. 50). Many were taken throughout December and on a few occasions in January, the last occurring on January 21. About the middle of December two other species (*Calliopius læviusculus* and *Gammarus annulatus*) suddenly appeared in abundance. The former often swarmed at the surface in large numbers, and individuals could be seen darting about in the water around the Fisheries dock throughout the spring months. *G. annulatus* reached its maximum after Calliopius had started to decline, although the collections of April often contained many specimens of both species. Verrill records great swarms of Calliopius far out at sea during this season. On one occasion they were found to be very abundant in the Gulf Stream.

After heavy northeast or southeast storms great numbers of amphipods are often found in the tow. At such times, however, many species usually appear. This condition characterizes the group and contrasts it with the first group, where one or two species make up the entire amphipod representation. These conditions are particularly obvious in summer. On July 24, 1922, after a hard northeast storm, seven species of amphipods and two species of isopods were taken in one day's collection. Such heavy offshore winds carry the surface waters out and cause an upwelling of bottom waters, carrying many of the bottom animals with them.

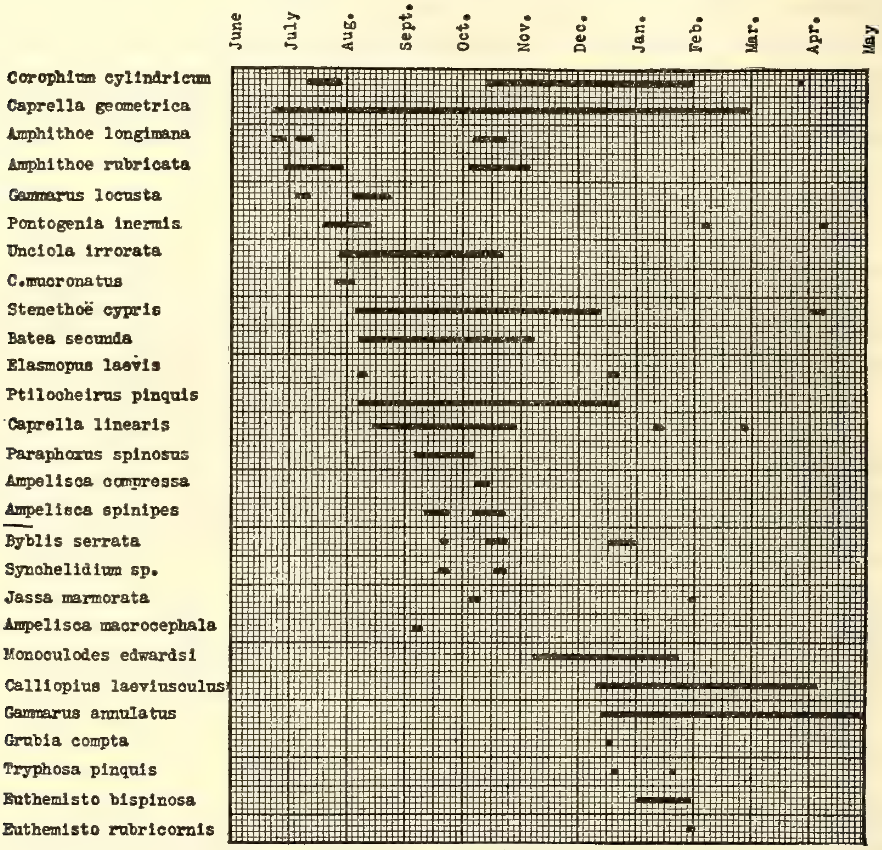

FIG. 52.—Occurrence of amphipods in surface collections from June, 1922, to May, 1923

The third group appeared only in summer. It was made up of the same species as the second group, but these occurrences were the result of different causes. Throughout the summer and particularly after the great diatom maximum the water was extremely phosphorescent. At such times the net appeared like a ball of fire as it swayed back and forth in the current. As the amphipods are positively phototropic, many, no doubt, are attracted by the light and are drawn into the net. Another factor as well may influence these collections which were always found more abundant at night. Experiments have shown that many amphipods rise to the surface at night and go down in the daylight. If this is true for many of the species, we should expect to find them more abundant in surface collections taken in the evening. How much effect this really has upon the plankton hauls I do not know, but I offer it as a possible explanation. I found no conditions in winter that could have resulted from such causes. Possibly the evening migrations do not take place during the cold season.

The following amphipods were taken in surface collections during 1922 and 1923:

Euthemisto bispinosa (Bœck).
Tryphosa pinquis (Bœck).
Paraphoxus spinosus, Holmes.
Ampelisca spinipes, Bœck.
A. macrocephala, Lilljeborg.
A. compressa, Holmes.
Byblis serrata, Smith.
Stenothoë cypris, Holmes.
Monoculodes edwardsi, Holmes.
Calliopius læviusculus (Kröyer).
Pontogenia inermis (Kröyer).
Batea secunda, Holmes.
Gammarus locusta (Linnæus).
G. annulatus, Smith.
Carinogammarus mucronatus (Say).
Elasmopus lævis (Smith).
Ptilocheirus pinquis, Stimpson.
Amphithöe rubricata (Montagu).
A. longimana, Smith.
Jassa marmorata, Holmes.
Grubia compta (Smith).
Ericthonius rubricornis, Stimpson.
Corophium cylindricum (Say).
Unciola irrorata, Say.
Synchelidium sp.
Caprella linearis, Linnæus.
C. geometrica, Say.

The Isopoda, with the exception of certain parasites, do not normally form a part of the plankton. They are most abundant in surface collections in summer. This is because numbers of Idothea and allied genera are found on floating Sargassum and Fucus, which, when carried into the nets or forced by them, often deposit many of their passengers. In winter this condition does not exist and few species are taken. On one occasion in the spring of 1900 many adult *Cirolana concharum* appeared in the tow. No doubt these were floating on a piece of wood or a dead fish which may have been carried into the net.

The most interesting by far of the isopods taken during the summer were four minute species of the family Bopyridæ, which are parasitic on copepods. These occurred in large numbers at certain times. Two species were found on *Acartia tonsa*, one on *Centropages typicus*, and one on *Labidocera æstiva.* They were most abundant from July to October, one specimen appearing unattached on December 20. None of the winter copepods seemed to be infested. No species have been recorded from this coast, and as a paper on these forms, now in the course of publication in England, is not yet completed, it was decided to wait for it before attempting to identify these isopods.

The following species were taken in 1922–23:

Idothea baltica (Pallas).
I. phosphorea, Harger.
I. metallica, Bosc.
Edotea triloba (Say).
Circolana concharum (Stimpson).
Tanais cavolinii, Milne Edwards.
Chiridotea cæca (Say).
Leptochelia savignyi (Kröyer).
Erichsonella filiformis (Say).
Family Bopyridæ, four species.

CUMACEA

The Cumacea occupy a place in the plankton similar to that of the amphipods. Large numbers are often taken at the surface during the breeding season, the females carrying eggs or larvæ. This particular group differs from the Arthrostraca in the length of the breeding season. Females of two species (*Diastylis sculpta* and *Cyclaspis variens*) were found carrying eggs at various times between July and January, although both species were most abundant in September and October. Females of *Oxyurostylis smithi* were also found with eggs on October 19. With the exception of the greater number taken during the breeding season, no particular time can be given for the occurrence of Cumacea in the plankton. They are found to be most abundant usually after a storm. *D. quadrispinosa*, which is reported to be abundant in this region, was not taken during the past year. The following forms were taken in 1922–23: *Cyclaspis variens* Calman, *Leptocuma minor* Calman, *Oxyurostylis smithi* Calman, *Diastylis polita* Smith, and *D. sculpta* Sars.

SCHIZOPODA AND STOMATOPODA

The larval stages, and often the adults (*Neomysis americana*) of the Mysidæ, at certain times of the year are very characteristic members of the Woods Hole plankton. The euphausiids, however, are "outside" forms and appear with other oceanic plankton only after southwest winds.

The Mysidæ, living among the eelgrass in shallow water, are not true pelagic animals, but an occasional adult may be carried into the net at any time. Certain species apparently never swim freely during the breeding season. *Heteromysis formosa* and a species of the genus Erythrops (new to the region) are examples of this type. The former species has been recorded for every month of the year. *Neomysis americana*, on the contrary, has a definite pelagic period and swarms in surface waters from December to April, inclusive. The larvæ appeared during the last week of April in 1899 and 1900 and continued in small numbers until July, the young being liberated in the form of the adults. In 1923 the first adult appeared on May 17.

Adult euphausiids have been recorded at various times by Edwards, but none are permanent inhabitants of this region. Their occurrence will be better understood when the distribution of the various species off the coast is more fully worked out. Five species from the surface collections of 1898, 1899, 1922, and 1923 were identified. On December 12, 1898, after a hard southwest storm, two *Thysanoëssa inermis* and one *T. longicaudata* were taken. There may be something in the occurrence of the former species to give a clue to its distribution. Zimmer gives it a wide range. It is a cold-water form, extending from the Vineyard Sound to the Gulf of Maine in the North Atlantic, always being found within the 50-fathom line. Records made to date seem to indicate a northerly migration throughout the summer months. The specimens recorded from Woods Hole were taken on December 12. The *Albatross* found scattered individuals in the deeper parts of Vineyard Sound in late July and August. Bigelow found it most abundant north of Cape Ann in early July and on German Bank in August, with minor centers of abundance off Penobscot Bay and in the northeast corner of the Gulf during the same month. Just as a northerly movement takes place in summer a southerly one is noticeable in late fall and winter. More complete data will be necessary to verify these statements, but it is evident that this species is most likely to be taken at Woods Hole from late fall until early spring.

The young of *Thysanoëssa longicaudata* in the late "cyrtopia" stage were comparatively abundant from May 10 to June 24, 1899. From this data it would seem that the adults enter the shallow waters during the breeding season of May and June. Bigelow found them abundant only in the center of the Gulf of Maine during the fall. This species, according to Zimmer, is also a cold-water form. It occurs occasionally in Vineyard Sound and quite frequently out beyond the Gulf Stream. As the young have never been taken since 1899, it is probable that the occurrence is not annual, but was due to unnatural conditions. Figure 53 gives the seasonal distribution for that year.

One specimen of *Euphausia krohnii* was taken on June 22, 1899, and another on November 9, 1922. Off the Atlantic coast they were taken in abundance in July and August. This is a southern species and may be expected to enter Vineyard Sound in the summer months. A single specimen of *E. tenera* appeared on October 30, 1923.

A battered specimen of the genus Thysanopoda was taken on June 23, 1922. The condition of the carapace made a determination of the species impossible. This was unfortunate because, although three species are recorded from the western Atlantic, each has been taken on only one occasion. *Thysanopoda æqualis* (H. J. Hansen) was recorded nearest the Woods Hole region.

A single specimen of *Meganyctiphanes norvegica*, taken April 25, 1906, was found in the surface collections of Mr. Edwards. This is a very common boreal Atlantic species, and it is surprising that more have not been taken in Great Harbor.

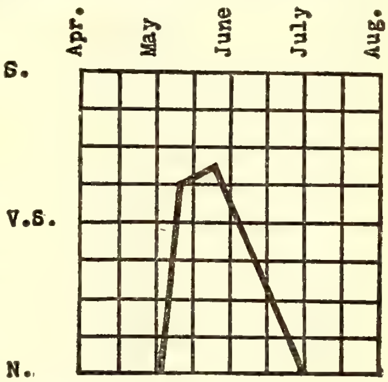

FIG. 53.—Occurrence of young of *Thysanoessa longicaudata* in surface collections of 1898 and 1899. (One adult on December 12, 1898)

The following Schizopoda were taken in surface collections at Woods Hole: *Thysanoëssa inermis* (Kröyer), *T. longicaudata* Kröyer, *Euphausia krohnii* Brandt, *Meganyctiphanes norvegica* (Sars), *Thysanopoda* sp., and *Euphausia tenera* Hansen.

Seven species of stomatopod larvæ have been recorded from the Woods Hole region, although but two species of adults occur here. Most of the larvæ are East Indian forms carried north by the Gulf Stream. The various members of the order are known to have an extremely long pelagic life with many larval stages. This, no doubt, accounts for the tropical larvæ occasionally appearing in Great Harbor. The larval Squillidæ are of two forms—the *Alima* and the *Erichthus* form. All the species recorded locally, with the exception of Chloridella, belong to the latter form.

Adult *Chloridella empusa* (Say) are rather scarce in the immediate vicinity of Woods Hole, and for that reason the larvæ are not abundant in the plankton.

In 1899 a single specimen was taken on August 7. None were observed in 1922. Figure 54 shows that the normal season is in August. Edwards's earliest record was in 1895, when several specimens were taken in August. His largest captures were made in 1905, when many appeared on October 21 and 22. Heretofore adults of Chloridella have been comparatively plentiful, but during the past few years they have gradually disappeared until they are now very rarely found. This explains the absence of larvæ in surface collections of recent years.

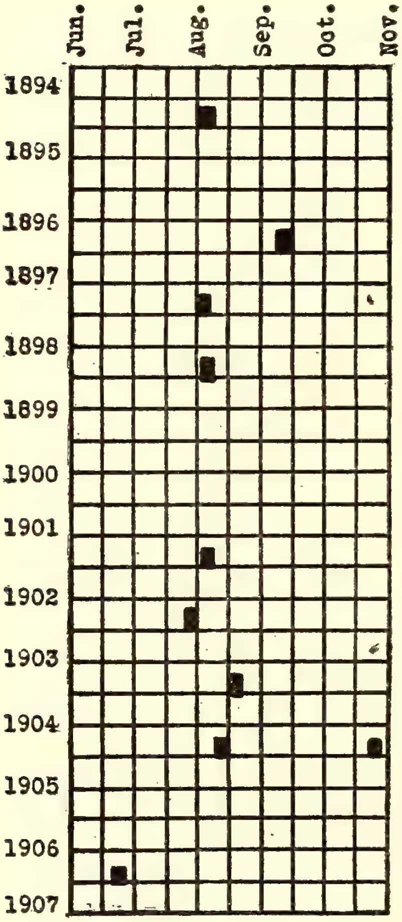

FIG. 54.—Occurrence of larval forms of *Chloridella empusa* in surface collections of successive years from 1893 to 1907

The Erichthus larvæ of *Lysiosquilla armata* Smith are among the most common on the southern coast of New England. They are usually found farther from the coast than Chloridella, probably because the adults are found in moderately deep water. *Chloridella empusa* is found on the muddy bottoms of bays and rivers. Vinal Edwards took 12 specimens of Lysiosquilla larvæ off Gay Head on September 12, 1902. Two specimens were taken in the same locality on August 15 and one on August 25, 1923, in Muskeget Channel.

Erichthus larvæ of two species of the genus Odontodactylus are recorded by R. P. Bigelow from this region. One was taken off Nantucket October 3, 1883, and the other at Woods Hole August 22, 1876. One of these appears to be the same as that incorrectly identified by S. I. Smith (1874) as the larva of *Chloridella empusa.* His specimens were taken in Vineyard Sound on August 11. In 1923 two specimens of Smith's species appeared in surface collections from Great Harbor on August 21 and three on August 22.

Bigelow considers these larvæ to be West Indian forms carried north in the Gulf Stream. Considering conditions existing during the past summer, this appears to be questionable. In 1922, when tropical plankton was abundant in local waters, none were found. In 1923 no Gulf Stream plankton or fish were taken, either in Vineyard Sound or Katama Bay. If these stomatopod larvæ are from the south, they are apparently the only tropical forms that found their way into shallow water this year. This seems hardly possible.

On July 17, 1908, Edwards found over 2,000 Erichthus larvæ in the stomach of a small mackerel taken at Woods Hole. Upon examination the author found them to be the young of the species of Odontodactylus figured by Smith. The specimens were for the most part entire and were probably found not far from Great Harbor. As one fish was able to capture more than 2,000, they must have been extremely abundant. It is difficult to see how such large numbers could have remained together in the long journey from the West Indies (where they never form a very considerable part of the plankton) to our coast and then not be scattered by the strong winds, which were necessary to blow them in. It is more probable that they are the young of an unknown species of the genus Odontodactylus inhabiting the deeper waters off the New England coast, possibly beyond the range of *Lysiosquilla armata*. Two unidentified species of Erichthus larvæ were taken by Verrill off Marthas Vineyard in August. One he suggests to be the larva of *Pseudosquilla ciliata* Miers. Both species were no doubt southern forms.

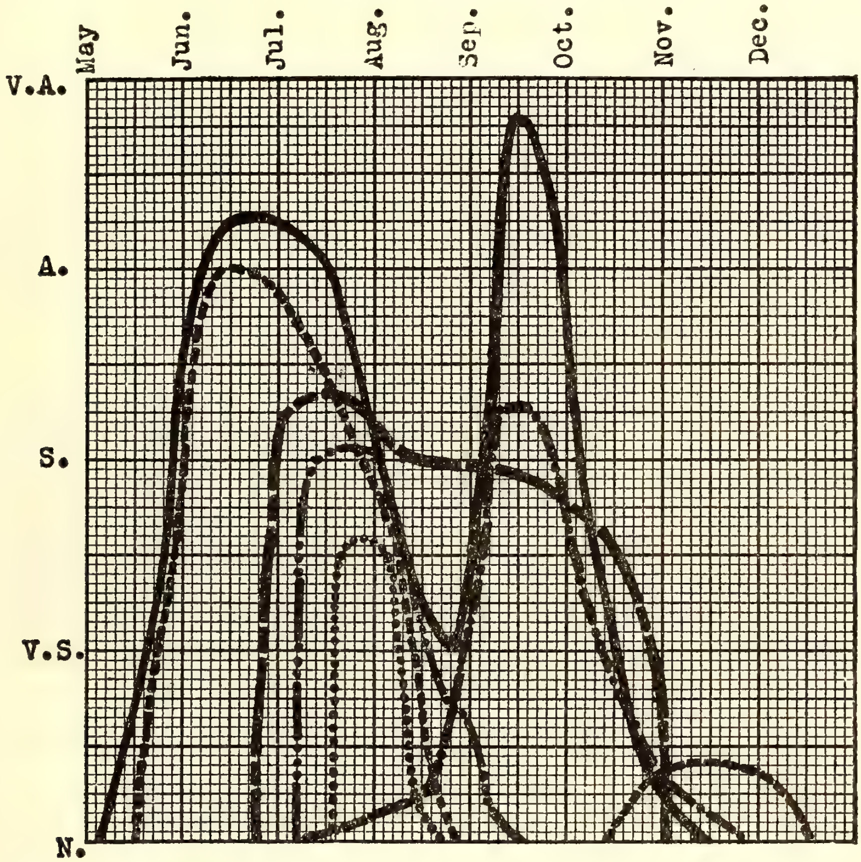

FIG. 55.—Occurrence of larval Macrura in surface collections of 1922. ———, Pagurus; • • • • •, *Crago septemspinosus;* —•— *Palæmonetes vulgaris;* —• • •—, *Naushonia crangonoides;* —•— *Hippolyte zostericola;* • • • • • • •, *Callianassa stimpsoni*

MACRURA

The Macrura form a very important part of the summer plankton. None of the members of this group are pelagic in adult life except some of the Caridea during the breeding season, but in all the larvæ are planktonic.

Usually the first larvæ to appear in the spring are those of *Crago septemspinosus*, but the spring of 1922 was unusually cold and for that reason none occurred during April. On April 21 several adult females bearing eggs were taken at the surface. This is characteristic of the species. In Narragansett Bay, on May 7, 1922, great numbers of adult females bearing eggs, as well as a few young, were taken in surface collections on a bright sunny day. Bumpus found young forms appearing in March at Woods Hole, while Thompson observed them as late as September 19. The first young were seen on February 1 in 1900. After this none were taken until April 3. From that day on they were abundant, declining in July and August. On October 17 the last specimen was taken. In 1922 the first of this species was noted on May 15, and great numbers were taken throughout July and early August. During the latter month there was a rapid decline, and none were taken from August 27 until October 29. On this date four specimens appeared. Scattered individuals were found in almost every haul until December 13, when a single Crago, 10 mm. long, occurred. In 1923 the first larvæ appeared on May 9 and the last, a specimen 6 mm. long, was taken on December 13. The maximum was reached early in July. All available records indicate that the normal season starts early in April, reaches its maximum in June or July, and usually ends in November.

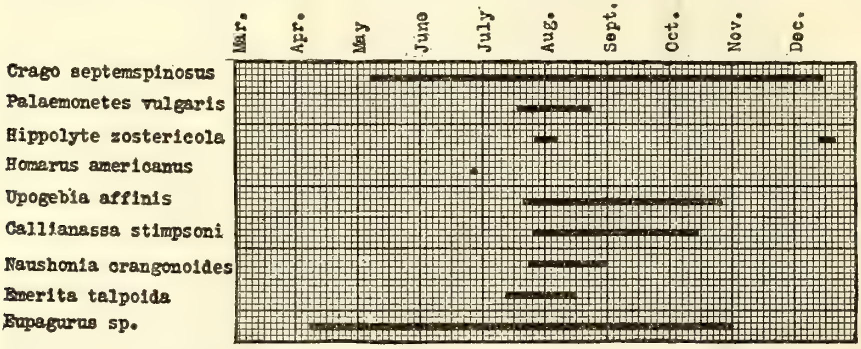

FIG. 56.—Occurrence of larval Macrura in surface collections of 1923

Palæmonetes vulgaris appears usually much later than Crago (figs. 55 and 56). Bumpus found females with early eggs on June 20. Throughout July and August the larvæ are very abundant, but all breeding ceases by September, according to Thompson. In 1899 larval Palæmonetes appeared suddenly in great numbers in the tow of June 15. Scattered specimens had been taken for a few days previous. From June until September 18 young in all stages of development were very abundant. From this date they declined rapidly and had practically disappeared by September 28, few specimens occurring after this. A single postlarval individual was taken on October 31. The first larvæ appeared on June 25, 1922. A gradual increase continued until the middle of July, when the maximum abundance was reached, followed by a gradual decline through August and September, late stages being taken throughout the month of October. The early larvæ are rarely found after the middle of September, however. In 1923 the first specimen was taken on July 16; the last on August 22.

Hippolyte zostericola was observed first in collections taken in the second week of July, 1922. Earlier records show that the young may occur at any time after July 1. The season is much more extended than that of either Crago or Palæmonetes, for very young specimens are often abundant throughout October. Scattering older larvæ were taken in November, the last appearing on November 18. Figure 55 shows the distribution of this species, which reached its maximum in September, 1922. In 1923 four early larvæ were taken on July 26. One late larval stage (4 mm.) appeared on December 13 and one on December 17.

Only three adults, including the type specimen, of the rare species *Naushonia crangonoides* have been found. Two of these were taken on the island of Naushon and one on the smaller of the Weepecket Islands. The distribution is much broader than has been supposed, however, because numerous larvæ appeared in surface collections from Katama Bay on the seaward side of Marthas Vineyard. Although the larval forms are never exceedingly abundant in the surface collections of Great Harbor, they occurred regularly in small numbers in almost every tow taken during the breeding season. The first specimens appeared on July 8, and the last were taken on September 19, 1922. The greatest numbers were found on July 24, although the average abundance was higher around August 1 (fig. 55). Figure 56 shows the distribution in 1923.

In spite of the fact that *Homarus americanus* breeds in great abundance in all the deeper waters of the region, larval forms are rarely taken in the plankton. During the summer of 1922 none were found in Great Harbor, although a single specimen appeared in surface collections from Vineyard Sound on July 24. As this larva was in rather a late stage, no doubt it had been clinging to the floating weeds, which were abundant in the net. The few captures of past years (fig. 57) were, with one exception, made during June and July. This appears to be the normal maximum season for the species in this region. A specimen taken on September 12, 1902, probably resulted from heavy winds, which were prevalent that year. On June 26, 1923, one was found after a hard southwest wind. A natural conclusion in the matter is that the larval lobsters under normal conditions do not form a part of the surface plankton but remain

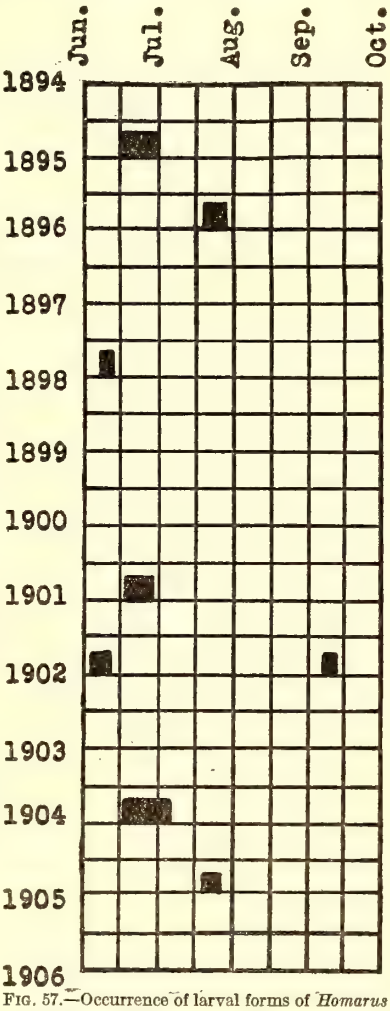

FIG. 57.—Occurrence of larval forms of *Homarus americanus* in surface collections of successive years, 1893 to 1907

near the bottom. Storms and strong currents may carry them to the upper strata, but the fact that they usually appear on only one or two days a year at the most indicates that their presence there is not normal.

Certain other Macrura were found occasionally in summer surface collections. *Emerita talpoida* was first taken on July 22, 1922, and continued to appear in small numbers until September 1, when four appeared, the greatest number found on any one day. Invariably these larvæ when placed in a watch glass would cast their shells and acquire the adult form within 24 hours. It was interesting to observe the little creatures as they labored continuously to dig into the glass bottom of the dish. After a time they would drop exhausted but could be made to resume their activity by disturbing the surface of the water.

Upogebia affinis was taken twice in August, 1922. In English waters larvæ of this genus are extremely numerous, but such is not the case at Woods Hole. The adults are not uncommon in this region, and in some years the larval forms may occur in greater numbers. In 1923 they were fairly abundant. The first specimen appeared on July 20; the last on October 25. The largest numbers were taken in early August.

The transparent larvæ of *Callianassa stimpsoni* Smith are frequently found in surface collections. Like Upogebia they are never found in abundance, although small numbers can usually be taken throughout July and August. In 1922 the first specimen appeared on July 16. After that scattered individuals were taken until the middle of August. The first larvæ were observed on July 26, 1923. From August 12 to 15 they were unusually numerous but soon declined again. The last specimen was taken on October 4.

The young of the many species of Paguridæ found in this region are always present in large numbers throughout the summer months. They are very similar to the larvæ of various Caridea but may be distinguished by the cephalothorax, which is drawn out in two points on the posterio-ventral margin. M. T. Thompson (1903) made a careful study of this group and described the development of the interesting larvæ. The early stages of the various species are almost identical, and in the case of the two most abundant forms—*Pagurus longicarpus* Say and *P. annulipes* (Stimpson)—it is impossible to distinguish them apart. Thompson found that *P. longicarpus* has the longest breeding season, extending from May until mid-September. Other species with eggs were found at different times during the summer. On April 8 of the present year (1923) two second-stage larvæ appeared. This is unusually early and far antedates any records for the region. No other specimens occurred during the month. On May 8, 1922, a single larva was taken. After this scattering forms appeared until June 1, when they became very abundant. Together with all other macroplanktonic animals they decreased during the summer diatom maximum (see figs. 15 and 55). In September the swarms appeared for a short time but soon declined, the last one disappearing on November 9. The first Glaucothoë was seen on July 13. After this scattering forms appeared throughout the summer, although they never were as abundant as the zoëæ. Their distribution in 1923 is shown on Figure 53.

The following Macrura were taken in the surface collections for 1922–23:

Crago septemspinosus (Say).
Palæmonetes vulgaris (Say).
Hippolyte zostericolà (Smith).
Naushonia crangonoides, Kinglsey.
Callianassa stimpsoni, Smith.
Homarus americanus, Milne-Edwards.
Emerita talpoida (Say).
Upogebia affinis (Say).
Pagurus sp.

BRACHYURA

Larval crabs are always present in the summer plankton in large numbers and form very important food for many fish. As few of the zoëæ had been worked out, they were a source of much trouble until the many forms were finally identified. The development of the various species will be taken up in a later paper.

All the crabs of this region have free-swimming larval stages, although certain species are seldom taken in surface collections. The megalops are found in smaller numbers than the zoëæ. Investigation showed that in this stage the young crab is usually found among the eelgrass and Fucus. It can swim as well as the zoëa but remains closer to the bottom. After hard winds large numbers were often taken in the nets. The megalops transforms into the "young crab" stage in a single molt. The "young crabs" are very rarely found swimming, except in the species *Pinnixa chætopterana* and *P. sayana.* These have no megalops stage but change directly from the zoëa into a young crab, which may be compared with the megalops of other species, for they swim about in much the same manner and are often very abundant in the plankton.

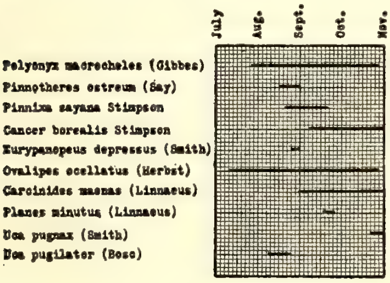

FIG. 58.—Brachyura occurring rarely in surface collections of 1922. Eggs of *Planes minutes* (Linnaeus) from an adult taken in the tow were hatched in the laboratory

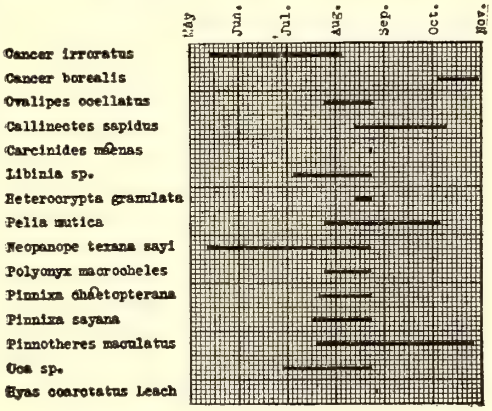

FIG. 59.—Occurrence of larval forms of Brachyura in surface collections of 1923. No observations were made from August 22 to September 18. Megalops of *Hyas coarctatus* Leach were obtained from Muskeget Channel on August 25

The zoëæ of Uca were rarely taken at the surface. Megalops appeared on only two occasions, after storms. This seems very strange, because Uca is probably the most abundant crab found in this region. Hymen reports the zoëæ as being very abundant in the surface collections at Beaufort, N. C., at all times during the summer. I believe that the fiddler crabs of this region have a very short larval period in which the zoëæ as well as the megalops remain at or near the bottom. *Carcinides mænas* larvæ may have similar habits, in this locality at least, for zoëæ were taken on only three days in October, 1922, and on one occasion in 1923 (figs. 58 and 59).

The females of *Pinnotheres maculatus* are commensal in Mytilus. The males swim freely about and were often taken during the breeding season but never after. Young males in all stages of development were frequently seen swimming. The young of this species formed one of the most abundant members of the plankton from July 6 to November 1, 1922 (see fig. 60). *P. ostreum* has similar habits but is not as common as *P. maculatus.*

The unusual larvæ of *Polyonyx macrocheles* occurred scatteringly from July 26 to October 29, 1922. These peculiar zoëæ differ from all other forms in the great length of the rostrum. On July 16, 1892, a sample of towings from Taunton River, Mass., was found to contain swarms of this species. Hardly anything else appeared. Faxon found the zoëæ swarming at the mouth of Massachusetts Bay in August, 1878. The adults are exceedingly rare. Agassiz found one adult at Newport under a stone, and Doctor Tennent collected one on Devil's Foot Island in a Chætopterus tube. G. Gray reports that several were found in Chætopterus tubes at Woods Hole in 1922. In 1923 the zoëæ were taken from July 20 until August 22 (see fig. 59).

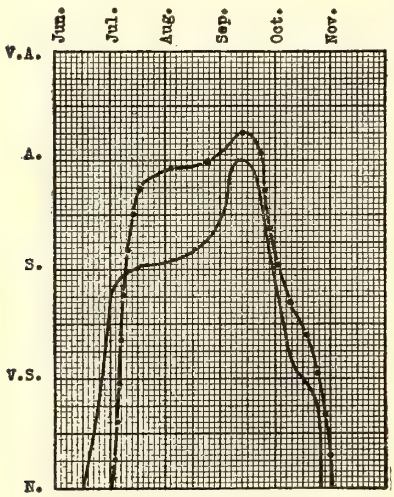

FIG. 60.—Occurrence of common grapsoid larvæ in surface collections of 1922. ———, *Pinnixa chætopterana;* —·—, *Pinnotheres maculatus*

The various species of crabs have definite breeding seasons, which often overlap each other. *Cancer irroratus* appears first, followed closely by *Neopanope texani sayi* (fig. 62). In 1922 the first zoëa of Cancer was observed on May 10. None appeared during April of the present year (1923), although many females bearing late eggs were taken on April 10 in lobster pots. Figures 60, 61, and 62 show the breeding seasons of the most abundant species taken in 1922, while the scarcer forms appear on Figure 58.

In 1922 another zoëa, almost identical to that of *C. irroratus,* was first found on September 8 and continued until October 31. This was undoubtedly *C. borealis,* although the megalops were smaller than those of *C. irroratus,* a smaller species. Adult specimens of *C. borealis* taken at No Man's Land on August 31, 1923, contained ripe eggs. The first larvæ appeared in Great Harbor on October 4; the last on October 28 (fig. 59).

The following brachyuran larvæ were taken at Woods Hole in 1922 and 1923.

Cancer irroratus, Say.
C. borealis, Stimpson.
Ovalipes ocellatus (Herbst).
Callinectes sapidus, Rathbun.
Carcinides mænas (Linnæus).
Libinia emarginata, Leach.
L. dubia, Milne-Edwards.
Eurypanopeus depressus (Smith).
Planes minutus (Linnæus).
Heterocrypta granulata (Gibbes).
Pelia mutica (Gibbes).
Neopanope texana sayi (Smith).
Polyonyx macrocheles (Gibbes).
Pinnotheres ostreum, Say.
Pinnixa sayana, Stimpson.
P. chætopterana, Stimpson.
Pinnotheres maculatus, Say.
Uca pugnax (Smith).
U. pugilator (Bosc).

PYCNOGONIDA AND XIPHOSURA

Pycnogonids are not pelagic animals, but live on hydroids and among the algæ, occurring in surface collections only when the objects to which they are attached float into the nets. For this reason they are usually taken during the summer months. Only one specimen appeared in collections made after October 1. That was on March 29 of the present spring (1923), when a single *Pallene brevirostris* Johnston was observed. This species is very abundant in the immediate region of Woods Hole and occurred almost daily during July and August. Females carrying eggs were found on August 21. On October 1, 1922, a male of *Tanystylum orbiculare* Wilson appeared. This was the only member of the species taken during the past year. A specimen of an unidentified genus new to the region appeared in August, 1922, and on July 23, 1923, a single *Anoplodactylus lentus* Wilson.

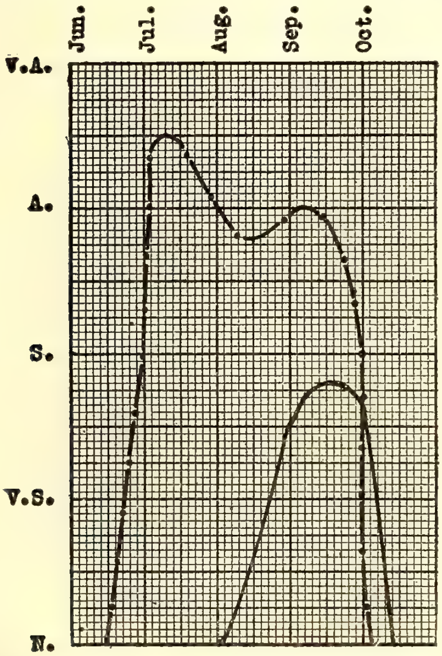

FIG. 61.—Occurrence of common larvæ of the tribe Oxyrhyncha in surface collections of 1922. —·—, *Libinia emarginata* and *L. dubia*, species not distinguished; ——, *Pelia mutica*

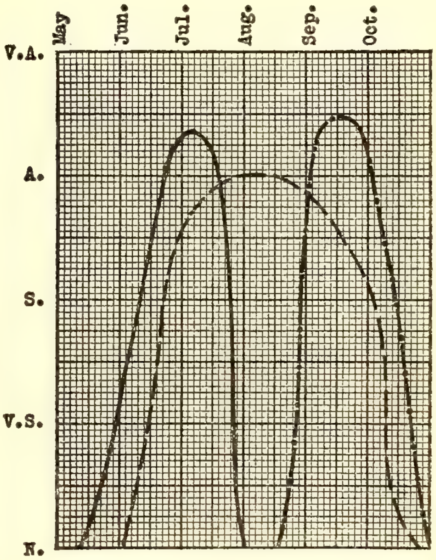

FIG. 62.—Occurrence of common larvæ of the tribe Cyclometopa in surface collections of 1922. ——, *Cancer irroratus;* — —, *Neopanope texana sayi;* —·—, *Callinectes sapidus*

Limulus polyphemus deposits eggs on sandy shores below the low-tide line. There are not many such spots about the bay in the vicinity of the "Hole," and for that reason few young are carried into Great Harbor. In certain localities, such as the sand flats at Duxbury, Mass., and Cold Spring Harbor, L. I., great numbers of the young forms in the so-called "trilobite" stage swim about at the surface. However, heavy shells prevent these animals from being very active members of the plankton, and consequently they are usually taken only in calm, shallow water. When disturbed, they become motionless and sink to the bottom, where it is almost impossible to distinguish them from the sand. None were taken in the surface collections of 1922; in fact, they are recorded only twice by Edwards in 15 years. In 1899 a few were taken on July 11 and again on July 12. In 1904 several appeared on August 9. On August 14, 1923, a single specimen was taken. As these are the only times that they have been seen here, it is probable that they are usually absent in surface collections except after northeast storms, when specimens may be transported from Buzzards Bay. The specimen taken in 1923 appeared after a hard northeast wind.

CHORDATA

After a storm on July 16, 1922, a postlarval *Balanoglossus aurantiacus* (Girard) was taken. On September 9 and 11 of the same year a single acidian larva, 1 mm. in length, appeared. They were the only representatives of this phylum seen during the year, excepting the Appendicularia, which at times appeared in great abundance. There were two species of the latter, one occurring during the summer and fall and the other in winter, the seasons almost overlapping. Both belong to the genus Oikopleura. On several days in the latter part of July, 1922, single specimens were noted. In August the number increased until they became very abundant. Throughout September, October, and November they grew scarcer, rapidly disappearing in December (see fig. 63).

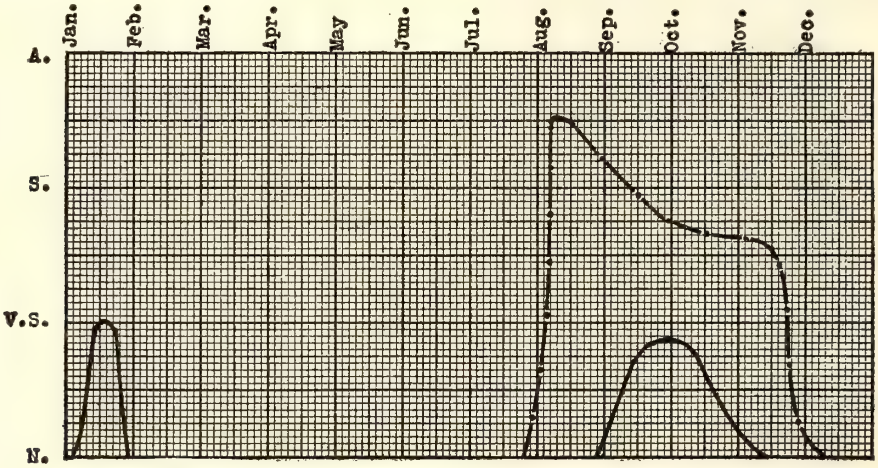

FIG. 63.—Occurrence of Appendicularia in surface collections from June, 1922, to December, 1923. —•—, distribution in 1922; ———, distribution in 1923

During October and November the "Haus," characteristic of Oikopleura, was taken. At times the tow contained hundreds of these pink "Häuser," each filled with copepods. One, on October 24, 5 mm. in length, was found to contain exactly 100 copepods; 97 of these were *Acartia tonsa*, 2 were *Centropages hematus*, and 1 was *Labidocera æstiva*. The contents of all had been removed, leaving only the outer transparent shell. Lohmann found that this "Haus" was often so delicate that the most minute organisms, which normally pass through the finest nets, were captured. In some forms the mesh gradually becomes finer toward one end. Undoubtedly those taken in my collections were not complete, for the wall mesh was comparatively coarse and both ends were broken. Lohmann gives 17 mm. as the average length of the "Haus" of *Oikopleura albans* Loeck. It is difficult to understand how copepods could be induced to enter such a small opening. Possibly, as in *O. albans,* the complete "Haus" is made up of two compartments—one of coarse and the other of fine mesh. The currents of water produced by the movement of the animal's tail cause microorganisms to collect in the fine mesh. This rich food center may attract the copepods, which crowd into the outer opening. The removal of the soft parts of the copepods was no doubt the work of protozoa. I have observed them completely clean out a decapod megalops in two days. The difficult thing to imagine, however, is how so many copepods could get into such a small amount of space. Lohmann found that a new "Haus" is secreted every six hours. This fact accounts for the great number taken.

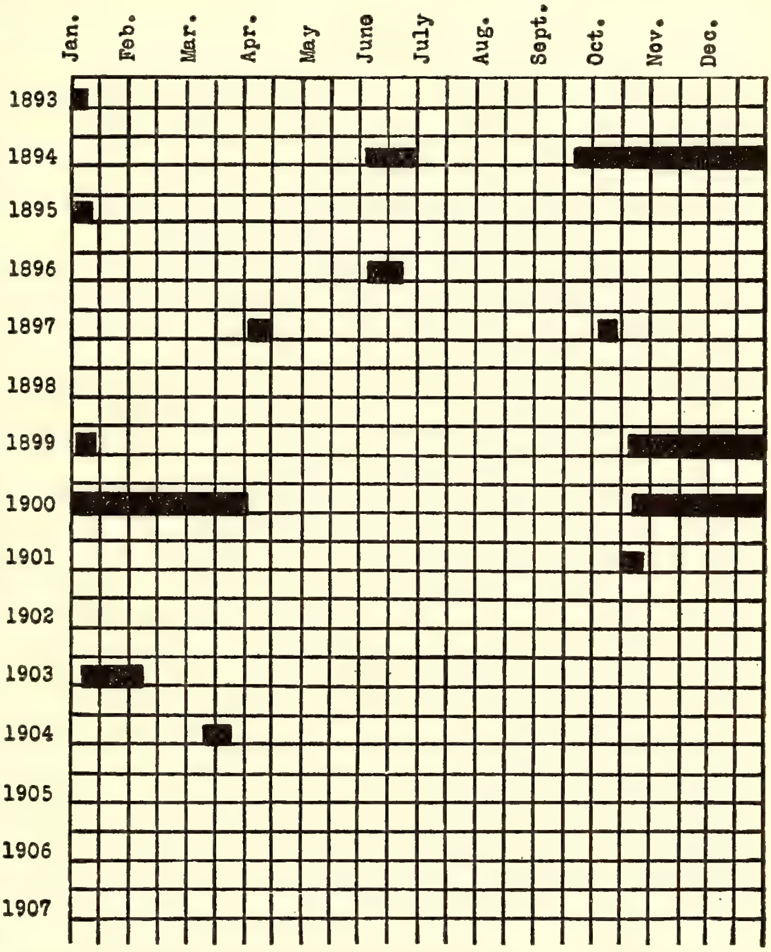

FIG. 64.—Occurrence of Appendicularia during successive years. No record was made after 1904

Only one species (*Oikopleura longicauda* (Vogt), listed by Pratt as *Appendicularia longicauda* (Vogt), has been recorded from the region. Neither member of the genus taken this year contains the "Kapuze" characteristic of Pratt's species. The winter form agrees very closely with, and probably is, *O. vanhoffeni* Lohmann, while the summer form has many of the characteristics of *O. dioica* Fol. At the time lack of sufficient literature prevented a final determination, and the preserved forms are not in a sufficiently good state of preservation to be identified positively.

In records of past years (fig. 64) the overlapping of fall and winter species shows very clearly. The winter type often appears as late as April, but disappears as soon as the temperature of the water rises. In 1894 and 1896 appendicularians appeared in large numbers in June. This is very unusual and may have been caused by an influx of Gulf Stream water.

Swarms of *Salpa democratica-mucronata* Forskäl blew ashore at Menemsha Bight in Vineyard Sound on January 11, 1901. None are recorded from surface collections in Great Harbor, but they may be expected at any time during that month after hard southwest winds.

FISH

Ehrenbaum states (in his excellent volume on the "Eier und Larven von Fischen") that the young stages of all fish, even those belonging to the bottom dwellers, are usually true planktonic forms during and often after their larval period.

From the standpoint of the planktonologist, fish of the Atlantic coast may be grouped roughly under two headings—those that have pelagic larvæ and those that have not. The latter group, of which *Opsanus tau* (Linnæus) is a striking example, contains very few members and does not enter into the plankton problem.

The first group is of great importance. A division may again be made here to separate those fish having pelagic eggs from those having demersal ones. No relationship exists between the condition of egg laying and the habits of the fish or between the various species of fish having these habits. Bottom-living forms, such as *Gadus callarias* and *Tautoga onitis*, have pelagic eggs while *Clupea harengus*, a surface dweller, has demersal ones. As a rule, most of the larger fish of this region belong to the group having buoyant eggs, the demersal group being composed of such small forms as Ammodytes, Pholis, Apeltes, Cyprinodon, Lucania, Fundulus, and Menidia. As many investigators have shown, special adaptations enable both types of eggs to have the best possible chance to survive.

In order to overcome the many difficulties besetting pelagic life, fish with buoyant eggs extrude enormous numbers of ova. These are small, translucent, and practically invisible against the bright sky, which forms the background. A very few species have pelagic eggs, which float together in a gelatinous membrane, often many feet in length. Such a condition is characteristic of *Lophius piscatorius*. The incubation period of pelagic eggs is comparatively short, largely governed by the temperature of the water. The young fish hatch in a very immature condition, and these, too, are translucent except for the eyes and scattering yellow and black chromatophores. For several days they are quite helpless, and undoubtedly during this period enormous numbers are destroyed. Later they become very lively, darting about and feeding ravenously on copepods. It is interesting to note that the eggs become translucent just before spawning. During development they are rather opaque, and the yolk is deeply colored.

Demersal eggs are laid in bunches on the sea bottom or attached to plants by fine threads. Here, again, there are special adaptations for fertilization and protection. Contrasted with the former group, where the females outnumber the males, McIntosh found that fish of this group are mostly males. This condition he believed to be necessary, for the milt rises and is likely to be lost before the eggs can be fertilized. The eggs are usually quite opaque and heavily laden with yolk. By being grouped in large bunches they are not so easily preyed upon by the bottom-feeding animals, although no doubt many are lost in this way. The eggs are comparatively fewer in number and have a longer incubation period.

Young fish of this group are often just as numerous in surface collections as those hatching from pelagic eggs, for they usually hatch in a much more advanced stage, thus greatly reducing the mortality.

Gadus callarias and *Pholis gunnellus,* characteristic members of the spring plankton, are excellent representatives of these two groups. The former emerge from the egg in a helpless condition and for some time are tossed about at the mercy of the waves as delicate little transparent larvæ. (The black chromatophores arrange themselves in vertical bands and may camouflage the young fish in much the same way that similar designs served to protect our ships during the late war.) The other species (*Pholis gunnellus*) is never found in an entirely helpless condition. The young, which are much farther advanced than those of the cod when they appear in surface collections, are always very lively and swim rapidly toward the light when placed in a glass tray. (The larval cod were always dead when removed from the nets.) Copepods were always found in the intestines of even the smallest specimens. This is further evidence of the activity of this species in its very early pelagic existence. The eggs are laid on the bottom in a compact mass and are guarded by the adult fish until hatched.

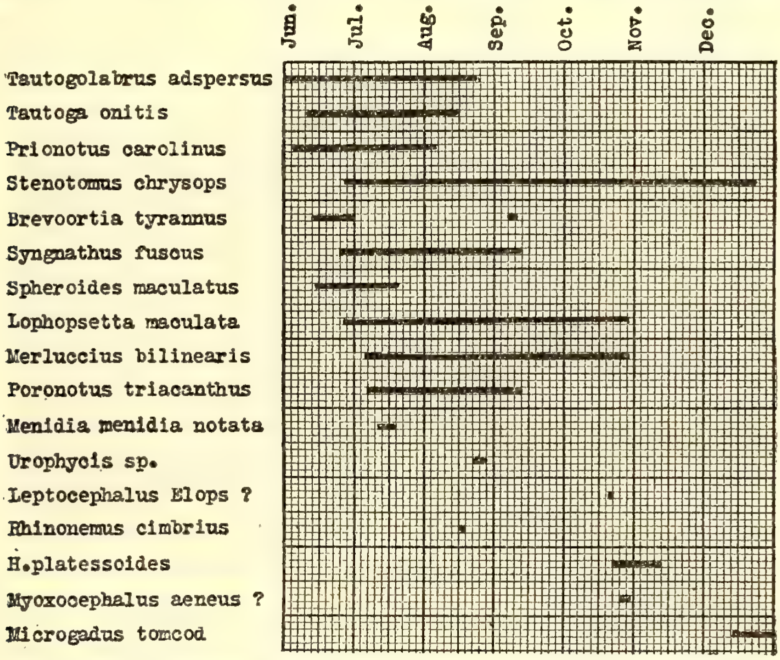

FIG. 65.—Occurrence of fishes in surface collections from June to December, 1922

In summer the most abundant larvæ are *Tautogolabrus adspersus* and *Tautoga onitis*. Both have pelagic eggs and appear in June, remaining until August. During this time the eggs are often very numerous, appearing like masses of minute bubbles on the surface in the examining dish.

Mr. Edwards took 34 species of larval fish in the 15 years recorded in Figures 67 to 81. During the past year 20 species were identified. Of the summer forms all but one (leptocephalus of Elops ?) are common to this region. The leptocephalus is not that of an eel but of a true fish, as the tail is well developed and forked. I have placed it in the genus Elops because that is the only common southern fish recorded from this region that has a leptocephalus stage.

Of the winter larvæ all were of species breeding in the region except *Gadus callarias*. This is a northern species common off southern New England, the adults of which never enter the immediate region. As the nearest important spawning grounds are on Nantucket Shoals, the appearance of early larvæ at Woods Hole probably results from southerly or easterly currents. Postlarval forms, usually about 20 mm. in length, find their way into this region and are often taken in May (fig. 67) in large numbers, depending upon the season. Still later postlarval stages (40 to 50 mm.) are always present in the shallow coastal waters in May and June. Many were taken within the boat basin at the Fisheries dock on May 24, 1923, with a fine net. During this period they are destroyed in large numbers by *Loligo pealii*. A school of over 200 of these squid, all about 5 inches in length, seined in Great Harbor, were found to be feeding entirely upon young cod. Several specimens were observed with a young fish protruding from the beak and one or more others held securely in the tentacles.

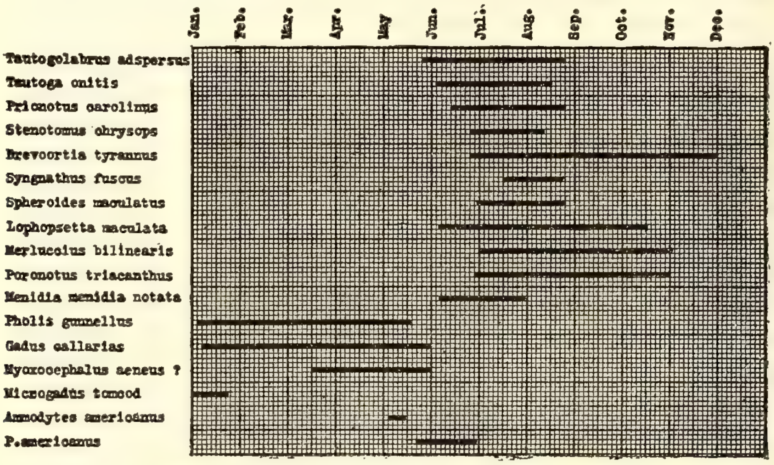

FIG. 66.—Occurrence of fishes in surface collections of 1923

In 1923 early larval stages of cod appeared in small numbers in the tows of January, February, and early March. Surface collections made in Vineyard Sound at various times during this period showed that they were present there also, but likewise in small numbers. Just what effect the artificial conditions created by the hatchery had is not known, but probably the 351,000,000 larvæ liberated during

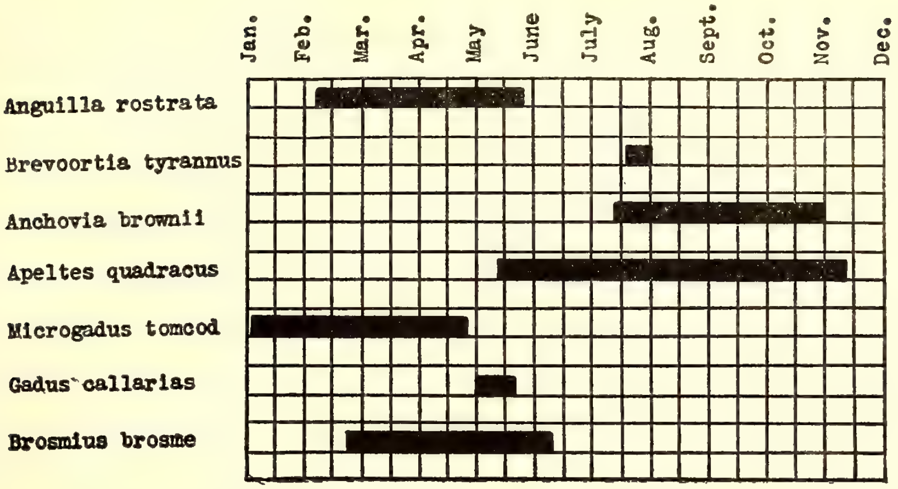

FIG. 67.—Maximum seasonal distribution of fishes not common in surface collections, based on records of the years 1893 to 1907

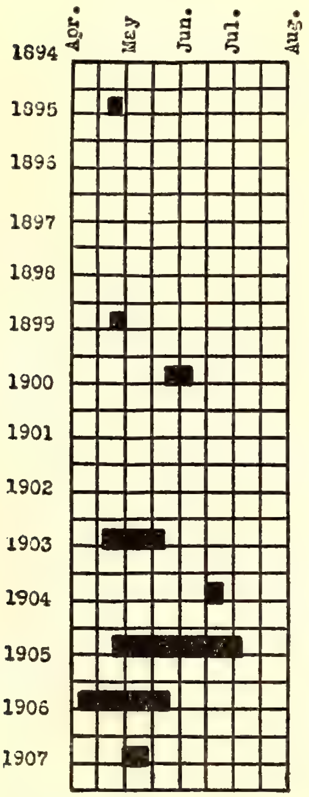

FIG. 68.—Occurrence of *Pholis gunnellus* during successive years, 1893 to 1907

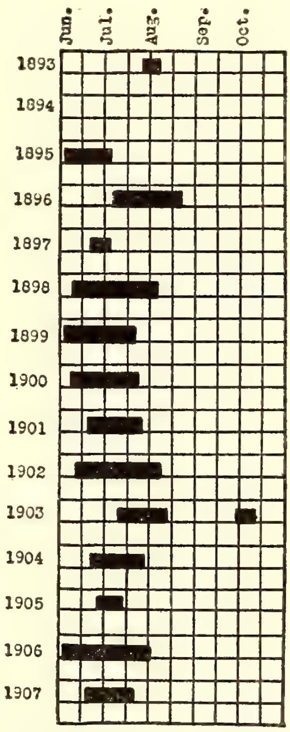

FIG. 69.—Occurrence of *Tautogolabrus adspersus* during successive years, 1893 to 1907

the spring less than a mile from the collecting station increased the surface catch somewhat. It is barely possible that all early specimens taken may have originated from that source. Their absence in records of past years, combined with their total absence during the early spring of 1924 (when no larval cod were liberated at Woods Hole), seems to substantiate this possibility. It must be remembered, however, that the unusually warm weather existing during the early part of the past winter apparently prevented the adult fish from spawning on their usual grounds, and for that reason no eggs were available at the hatchery. The cod may have sought deep areas so far from the coast that the early forms, which were never abundant in this region anyway, could not be transported into these waters. Fishermen reported that they had never known the cod catch to be so small on the southern New England grounds as during the early winter of 1923. They were totally unable to supply the Woods Hole station with any spawning fish. The usual fall school which annually enters Narragansett Bay also failed to appear. It will be interesting to learn whether the postlarvæ appear as usual in May, 1924.

In Figure 67 and Table 5 several fish taken rarely in past years are listed. Most of these are southern forms and occur only in the summer when the Gulf Stream inhabitants are blown in. *Lactophrys trigonus*, *Cryptacanthodes maculatus* *Anarhichas lupus*, and *Seriola zonata* are representatives of this fauna.

TABLE 5.—*Fishes very rarely taken in surface collections*

Species	Date	Abundance
Leptocephalus conger	Jan. 13, 1903	One.
Osmerus mordax	Feb. 28, 1895; July 14 and 15, 1896; and June 19, 1899	Many.
Poronotus triacanthus	Aug. 9 and 10, 1898	Few.
Lactophrys trigonus	Sept. 26, 1893	Many.
Cyclopterus lumpus	June 20, 1898; June 5, 1905; and June 18, 1907	Do.
Cryptacanthodes maculatus	Apr. 22, 23, 25, and 26, 1907	Do.
Anarhichas lupus	May 1 and 2, 1899, and June 3 and 5, 1899	Few.
Rhinonemus cimbrius	Apr. 1, 27, 28, and 30, 1900; June 2, 3, 4, 5, and 6, 1906; and July 17, 1906	Very many.
Lophius piscatorius	June 10, 1899	Few.
Pseudopleuronectes americanus	Apr. 13, 1897	Many.
Limanda ferruginea?	Jan. 4, 1908	One.
Seriola zonata	Aug. 30, 1907	Few.
Pomolobus pseudoharengus	July 13, 1896	Do.

The remaining figures show clearly that the fish have a definite breeding season within certain limits, usually determined by temperature. Temperature chart for the spring of 1923 (fig. 5, opp. p. 100) indicates how unusually cold the water was. The result was that many of the fish, as well as other larval forms, did not appear. The approximate temperature throughout the breeding season of each common species may be found by comparing the individual figures with Figures 4, 5, and 6. This particular temperature, however, must not be regarded as the complete governing factor. At some time earlier in the year a rise or fall in temperature caused the ovaries and testes to ripen. When the sex products have completely matured they will be extruded within certain limits irrespective of temperature. After this extrusion the immediate temperature then plays its part. Cod eggs have been made to hatch in 9 days or 64 days by varying the temperature of the water.

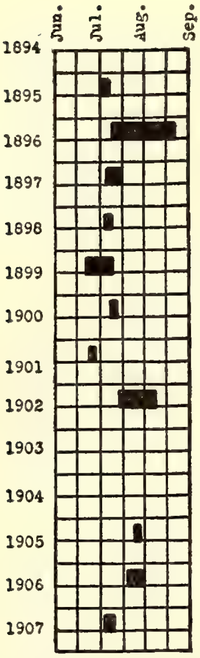

FIG. 70.—Occurrence of *Tautoga onitis* during successive years, 1893 to 1907

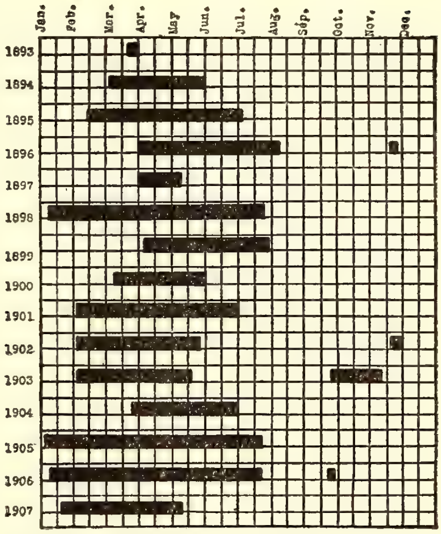

FIG 72.—Occurrence of *Ammodytes americanus* during successive years, 1893 to 1907

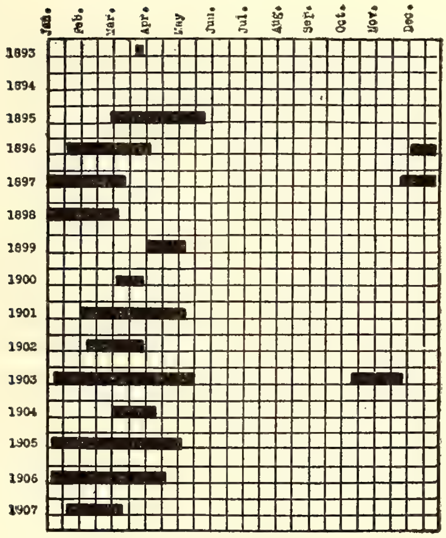

FIG. 71.—Occurrence of *Myoxocephalus æneus* during successive years, 1893 to 1907

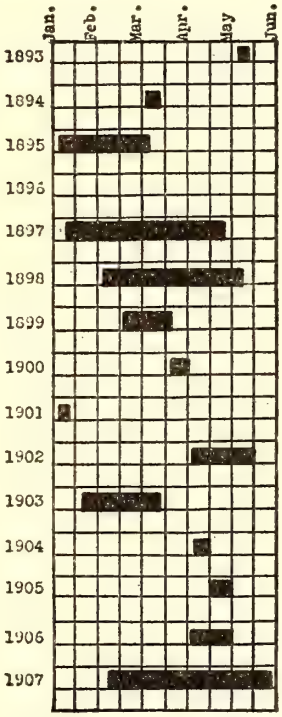

FIG. 73.—Occurrence of *Pollachius virens* during successive years, 1893 to 1907

As the salinity of Woods Hole is not noticeably different from the outer waters, it probably plays no part in the distribution of the larval fish of this region. The governing factors are, then, temperature and food, if we omit the effect of winds and currents, which at times may influence the distribution greatly.

The abundance of food has a powerful effect on the lives of the young fish. Given favorable temperatures, the larvæ will develop rapidly and in great numbers if food is plentiful. If food is scanty, few larval fish will be found. During the winter and spring months copepods make up practically the entire food of the young forms. The most abundant copepods during colder weather are usually *Temora longicornis* and *Pseudocalanus elongatus.* No doubt both of these species contribute equally to the food supply. As the spring of 1923 was exceptionally cold, Temora did not appear. Scattering forms were taken during the winter, but never more than three or four specimens on any one day. Out of 200 examinations of stomach contents of larval fish this spring not a single Temora was found. *Pseudocalanus elongatus* and *Centropages hematus* were very plentiful, particularly the former, and these constituted their food, the bright red color of the Pseudocalanus showing clearly through the thin walls of all the young fish collected.

The summer fishes have a much greater variety of food and for the most part do not limit their menu to Copepoda, although *Acartia tonsa* and *Centropages typicus* are eaten in great numbers. A young puffer (*Spheroides maculatus*), 3.5 mm. in length, examined on June 28, 1922, was found to contain 12 *Littorina litorea,* 9 *Venus mercenaria,* and 2 *Acartia tonsa.* Often a young fish was taken with a large copepod or phyllopod protruding from its mouth.

The relationship of the larval fish to its food supply is therefore very close, and one must determine it accurately in order to understand the distribution of a species. Such a study was attempted at the Plymouth laboratory by Doctor Lebour, who obtained some interesting results. More extended observations will be necessary before the relationship of the many factors can be clearly understood.

The following forms were taken in surface collections of 1922–23:

Tautogolabrus adspersus (Walbaum)	Cunner.
Tautoga onitis (Linnæus)	Tautog.
Prionotus carolinus (Linnæus)	Sea Robin.
Stenotomus chrysops (Linnæus)	Scup.
Brevoortia tyrannus (Latrobe)	Menhaden.
Syngnathus fuscus Storer	Pipefish.
Spheroides maculatus (Bloch and Schneider)	Puffer.
Hippoglossoides platessoides (Fabricius)	Sand dab.
Merluccius bilinearis (Mitchill)	Whiting.
Poronotus tricanthus (Peck)	Butterfish.
Menidia menidia notata (Mitchill)	Silversides.
Pholis gunnellus (Linnæus)	Rock eel.
Urophycis	Hake.
Gadus callarias Linnæus	Cod.
Leptocephalus, Elops?.	
Microgadus tomcod (Walbaum)	Tomcod.
Myoxocephalus æneus (Mitchill)?	Sculpin.
Lophopsetta maculata (Mitchill)	Window-pane.
Rhinonemus cimbrius (Linnæus)	Rockling.
Ammodytes americanus De Kay	Sand launce.

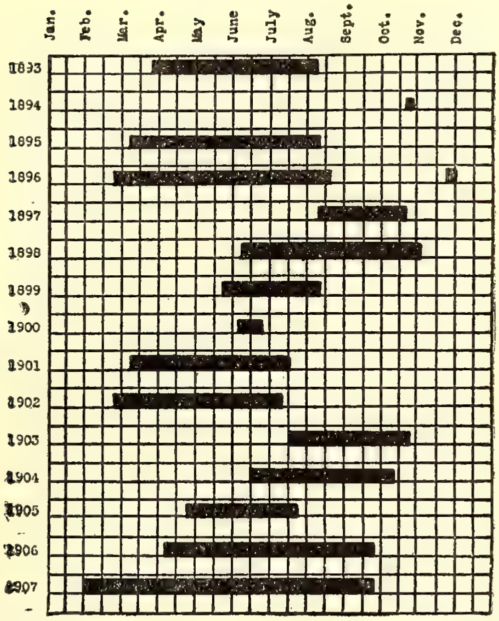

FIG. 74.—Occurrence of Urophycis sp. during successive years, 1893 to 1907

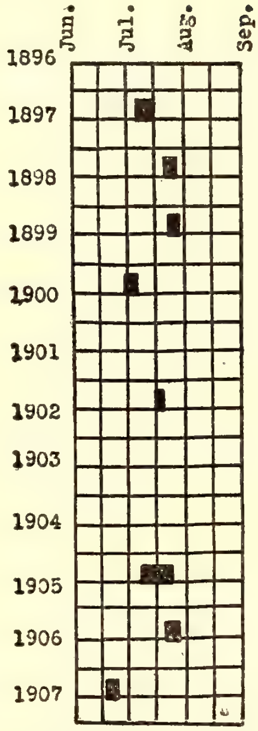

FIG. 75.—Occurrence of *Stenotomus chrysops* during successive years, 1893 to 1907

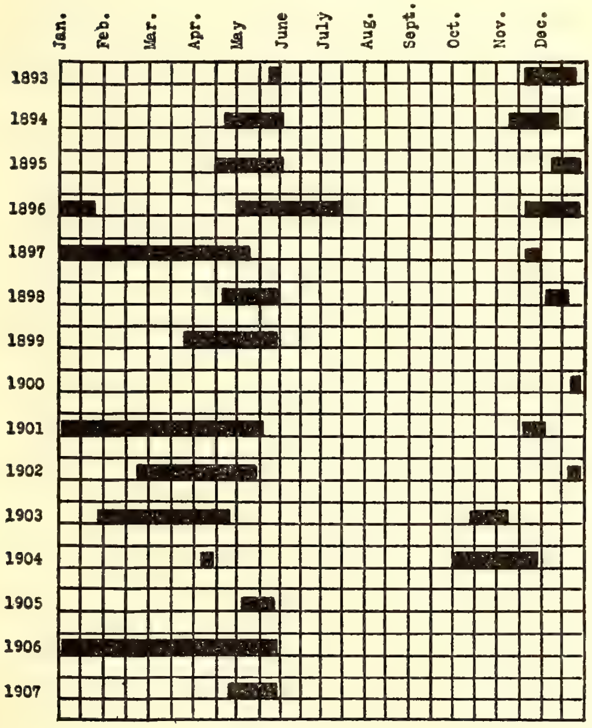

FIG. 76.—Occurrence of *Clupea harengus* during successive years, 1893 to 1907

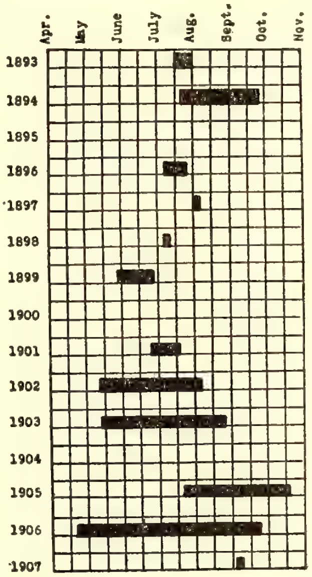

FIG. 77.—Occurrence of *Syngnathus fuscus* during successive years, 1893 to 1907

The following fish were taken in surface collections of 1893 to 1907:

Anguilla rostrata (Lesueur).
Leptocephalus conger (Linnæus).
Clupea harengus Linnæus.
Brevoortia tyrannus (Latrobe).
Anchovia brownii (Gmelin).
Osmerus mordax (Mitchill).
Apeltes quadracus (Mitchill).
Syngnathus fuscus Storer.
Menidia menidia notata (Mitchill).
Ammodytes americanus De Kay.
Poronotus tricanthus (Peck).
Stenotomus chrysops (Linnæus).
Tautogolabrus adspersus (Walbaum).
Tautoga onitis (Linnæus).
Lactophrys trigonis (Linnæus).
Spheroides maculatus (Bloch and Schneider).
Myoxocephalus æneus (Mitchill)?.
Cyclopteras lumpus Linnæus.
Pholis gunnellus (Linnæus).
Cryptacanthodes maculatus Storer.
Anarhichas lupus Linnæus.
Prionotus carolinus (Linnæus).
Pollachius virens (Linnæus).
Microgadus tomcod (Walbaum).
Gadus callarias Linnæus.
Urophycis sp.
Rhinoneumus cimbrius (Linnæus).
Brosmius brosme (Müller).
Lophius piscatorius Linnæus.
Pseudopleuronectes americanus (Walbaum).
Hippoglossoides platessoides (Fabricius).
Lophopsetta maculata (Mitchill).
Pomolobus pseudoharengus (Wilson).
Seriola zonata (Mitchill).
Limanda ferruginea (Storer)?.

GENERAL CONCLUSIONS

I shall not attempt to summarize all the conclusions arrived at during the past year. For the most part these have been taken up under the various subjects and in the discussion on plankton. The following are some of the more general conclusions concerning the nature of the plankton and the physical factors affecting its distribution, resulting from a 2-year study of the Woods Hole pelagic fauna:

1. Woods Hole is an excellent location for the study of the seasonal distribution of plankton.

2. It is impossible to investigate diurnal distribution in Great Harbor. The current rushing through the passage during the flood tide mixes the water so completely that the distribution of plankton remains the same at all times. The entire body of water is affected at the same time, even during periods of sudden heating or rapid cooling of the air.

3. No great amount of fresh water enters Woods Hole. The salinity averages about 31.5. For this reason titrations are of importance in determining the presence of ocean water.

4. As in the case of the benthonic animals, the plankton of this region is made up of a complex of faunas. It forms the northern limit of many southern species, the southern limit of many northern species, and a pocket where oceanic animals blown in by strong southerly winds are deposited.

5. The tropical species appear gradually in Great Harbor in the summer, but stop suddenly in the fall. This is because the temperature of the water in Buzzards Bay rises higher than that of the coastal waters in summer but responds quickly to the falling temperature of the air and by fall becomes much colder. Animals carried into this region in summer survive, but in the fall the lower temperature proves fatal and few live to be carried through the passage back into the deeper waters. However, members of this group may be taken throughout the fall in Vineyard Sound, where the decline in temperature is not so rapid.

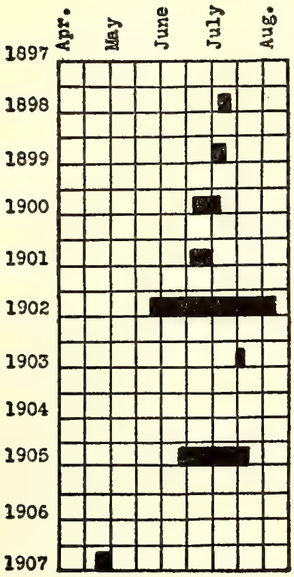

FIG. 78.—Occurrence of *Prionotus carolinus* during successive years, 1893 to 1907

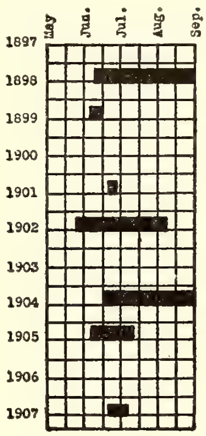

FIG. 80.—Occurrence of *Hippoglossoides platessoides* during successive years, 1893 to 1907

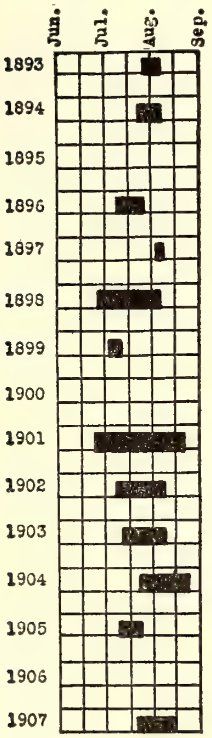

FIG. 79.—Occurrence of *Spheroides maculatus* during successive years, 1893 to 1907

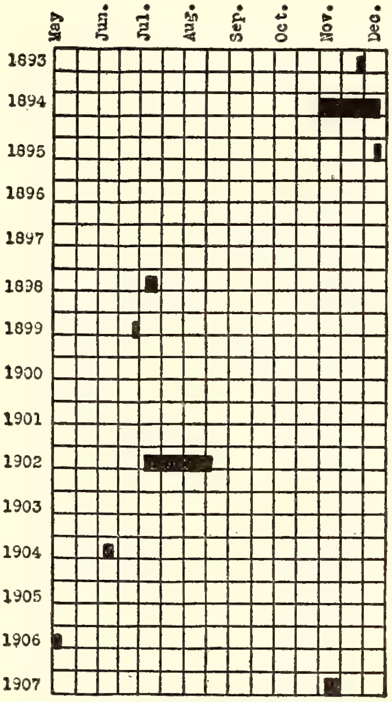

FIG. 81.—Occurrence of *Menidia menidia notata* during successive years, 1893 to 1907

6. The arm of Cape Cod forms a permanent northern barrier for the southern neritic plankton but only a summer barrier for northern pelagic species.

7. The proportion of benthonic animals occurring in the plankton of this region is much greater than that found in normal littoral plankton. After northeast storms Buzzards Bay types predominate; after southerly storms Vineyard Sound types are most plentiful. This is particularly noticeable in the case of amphipods.

8. No correct impression of the relative abundance of the local benthonic fauna can be obtained from surface collections unless the distribution of each of these animals in the bay and sound is completely understood.

9. A distinct periodicity in the occurrence of all the common animals of the region is clearly noticeable. The succession of species remains almost the same each year, the only variation being in the time of their appearance and disappearance.

10. The planktonic animals of the region, with one exception, may be placed in two general groups—the summer community and the winter community. The cœlenterates are the exception. For the most part these have a long spring maximum and a short one in the fall.

11. The pelagic diatoms exert a very great influence on the zooplankton. When the greatest maxima appear most of the zooplanktonic forms disappear. There are possibly two reasons for this. First, the common species having these swarming periods do not form the food of the zooplankton so far as I have been able to determine. During the maxima of the larger diatoms the smaller members of this group which are eaten by pelagic animals disappear, causing a scarcity in the food supply. This may account for the similarity in the time of disappearance of the larger forms and the small diatoms. Second, the great numbers of the diatoms filling the water apparently cause conditions unfavorable for animal life of any sort. The macroplankton seems to be literally choked out. This, however, is hardly probable, and is offered merely as a possible explanation.

12. Conditions favoring the increased production of one species of diatoms are also favorable for many others, provided that one does not become so abundant that almost all others disappear. The summer maximum often exemplifies the latter condition. The winter swarm usually consists of many species in which various forms predominate at different times.

13. My observations on the distribution of pelagic diatoms lead me to disagree with the theory that all production takes place in deeper waters off the coast, the species occurring in the littoral waters being the result of winds and tides. Such factors no doubt account for the distribution of the various species, but the quantitative distribution can not always be explained on that basis.

All evidence points clearly to the fact that great production of floating diatoms takes place at the mouths of rivers where the largest amount of drainage from the land is emptied into the coastal waters. Peck's observations in Buzzards Bay also indicate that the greatest swarms are found where the greatest outwash from the land occurs. Buzzards Bay is a great reservoir in which pelagic diatoms accumulate and multiply, and as a result the swarms carried into Great Harbor are often exceedingly large.

14. Temperature is the dominant factor in governing the seasonal distribution of all local pelagic animals. It also determines whether oceanic species entering the region shall perish at once or live long enough to become an important factor in the local fauna. Three general conditions cause the appearance of the pelagic animals—winds, tides, and the food supply. Salinity forms barriers in some localities, but not at Woods Hole. Once introduced into the region, the organisms remain until the temperature becomes unfavorable or the food supply is exhausted, and then they must leave or perish. Food is also an important factor in causing the disappearance of a species during a period of favorable physical conditions. This is probably the limiting factor of the summer diatom season. Temperature governs the breeding seasons of all planktonic and benthonic animals of this region. The temperature prevailing at the time of the extrusion of the eggs is not often the important factor, for the eggs are usually thrown off as soon as ripe, provided the conditions are not too unfavorable. After the eggs have been deposited in the waters the existing temperature plays a part in determining whether the incubation period will be long or short. The determination of an early or a late breeding season, then, depends upon the temperature at some previous date when a warming or cooling of the water started the development of the sex products. This fact must be considered when interpreting the appearance of certain larvæ in the plankton.

15. Reactions to changes of temperature are for the most part more evident among planktonic animals than among benthonic forms. Bottom dwellers, particularly sessile forms, in order to maintain themselves must be able to withstand a great range of temperature. Unusually low temperatures often kill large numbers, but as a rule both the larvæ and adults are extremely hardy. This is not true in the case of planktonic forms. Certain species, such as *Calanus finmarchicus*, although preferring cold water, are able to stand sudden rising or falling temperatures and appear to survive as well in water of 22° C. as at 0° C. Most pelagic animals, however, particularly the phytoplankton, disappear as soon as the temperature conditions become unfavorable.

16. The annual distribution of the diatom maxima of the American coast is very similar to that of the eastern Atlantic waters in that the seasons of the greatest swarms retreat farther and farther from the warmest months as one approaches the Tropics. A similarity in the seasonal variation in European and American waters of the same latitude is particularly noticeable, conditions at Woods Hole corresponding to those in the Adriatic Sea. The great effect of the arm of Cape Cod on the local plankton is again evident here, for within 20 miles of Massachusetts Bay, with conditions similar to the Norwegian Sea, conditions comparable to those of the Mediterranean and Adriatic Seas are found in Buzzards Bay.

17. The distribution of the plankton of the western Atlantic coast is little understood, and the number of animals new to the region taken during the past year indicates that most of the eastern Atlantic coast pelagic species probably will be found here also.

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DIGESTIVE ENZYMES IN POIKILOTHERMAL VERTEBRATES. AN INVESTIGATION OF ENZYMES IN FISHES, WITH COMPARATIVE STUDIES ON THOSE OF AMPHIBIANS, REPTILES. AND MAMMALS

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INTRODUCTION

The literature on digestion in poikilothermal vertebrates shows a need for further investigation, especially by systematic comparisons of the digestive enzymes in representatives throughout the vertebrate series. It would be of value to know if differences in digestive enzymes have occurred in the course of evolution of groups of higher vertebrates from more primitive ones, with the migration of aquatic vertebrates to land habitats, and with the metabolic changes necessitated by the transformation from a poikilothermal to a homoiothermal condition. It would also be of interest to know more of relations of digestive enzymes to different types of alimentary structure and the adaptations of digestive enzymes to differences in food habits.

Comprehensive reviews of previous works have been published by Yung (1899), Sullivan (1907), and Biedermann (1911). Since a review of early literature would be largely a repetition of the essence of these reviews, the reader who desires further information in regard to early studies on digestion in fishes is referred to these articles.

It is obvious in the records of previous investigators that there has been much difference of opinion in regard to digestion in fishes. Much of the inconsistency in results is doubtless due to the fact that in most of the investigations careful quantitative methods with well-regulated hydrogen ion concentrations have not been employed. In fact, the greater part of the studies made upon digestion in fishes was made before the development of improved quantitative methods and especially before the development of accurate methods for hydrogen ion regulation. The study of digestive enzymes in amphibians and reptiles has been almost wholly neglected.

The only record that the writer has been able to find of any attempt to compare the rate of digestion in different groups of poikilothermal vertebrates is that of Riddle (1909), which, unfortunately, yielded no conclusive results of a comparative nature.

Recently Bodansky and Rose (1922) published a preliminary study on digestion in certain elasmobranchs and teleosts, employing well-controlled hydrogen ion concentrations. Using Dernby's (1918) method of liquefaction of gelatin as criterion for proteolytic digestion, they found that the optimum pH for gelatin digestion by fish pepsin was about 3. This is in agreement with the optimum for mammalian pepsin. These investigators found coagulated egg albumin to be very slowly digested by the proteolytic enzymes of fishes. From extracts of the pyloric caeca of the red snapper (*Lutjanus aya*) they obtained trypsin, pepsin, rennin, amylopsin, and lipsæ (weak). Invertase was present to a very slight extent; inulinase, maltase, and lactase were altogether absent.

PURPOSE OF THE INVESTIGATION

The purpose of the investigations described in the present paper has been twofold: (1) To make a comparative study by means of reliable qualitative and quantitative methods of the rate of digestion by the more important digestive enzymes in representative fishes, amphibians, and reptiles, with less extensive studies on those of mammals; and (2) to extend the present knowledge of the presence, character, and distribution of proteolytic and carbohydrate-splitting enzymes in the animals studied.

The work has extended over a period of two years. Many of the experiments upon fishes were performed while the writer was employed by the United States Bureau of Fisheries during the summers of 1922 and 1923. The writer is especially indebted to Dr. A. S. Pearse and to Dr. H. C. Bradley, of the University of Wisconsin. for valuable suggestions and criticisms.

ANIMALS USED IN THIS WORK

The following fishes have been used in this investigation: Bluegill, *Lepomis incisor* (Cuvier and Valenciennes); carp, *Cyprinus carpio* Linnæus; black crappie, *Pomoxis sparoides* (Lacépède); pickerel, *Esox lucius* Linnæus; perch, *Perca flavescens* (Mitchill); sucker, *Catostomus commersonii* (Lacépède); and white bass, *Roccus chrysops* (Rafinesque). Of these the pickerel, as a representative of carnivorous fishes, and the carp, that is mainly vegetarian in its diet, have been the most thoroughly studied. The principal amphibian studied was the mud puppy, *Necturus maculosus* Rafinesque. Among the reptiles the bull snake, *Pituophis sayi* (Schlegel); snapping turtle, *Chelydra serpentina* (Linnæus); and the painted turtle, *Chrysemys belli* Gray and *C. cinera* (Bonnaterre), which intergrade in this locality, were used. The dog was selected as a representative mammal.

DESCRIPTION OF METHODS

The reaction in the esophagus, stomach, and intestine of various animals was determined approximately by means of indicator papers as soon as possible after killing the animal.

For digestion studies the fresh alimentary tract was thoroughly washed and cleaned from traces of pancreatic tissue and mesentery. When the stomach contained substances in process of digestion, it was ligated at both ends to prevent passage of its contents into the esophagus and intestine while being cleaned. Then the tract was cut into the divisions to be studied, each division opened by a longitudinal slit, and the contents thoroughly washed out with the view of preventing any contamination of mucosa of one region with enzymes from other sources. After cleaning the mucosa or other digestive tissue was removed, weighed (moist), and triturated in a mortar with the aid of crushed glass when necessary. The finely ground tissue was made into a brei containing 10 per cent toluol, 40 per cent tissue for proteolytic enzymes or 25 per cent tissue for carbohydrate-splitting enzymes, with distilled water to 100 per cent. The brei was allowed to extract two to three days at room temperature and was strained through two thicknesses of cheesecloth.

Coagulated egg white was used as substrate for pepsin and trypsin. It was prepared in considerable quantity and preserved in 10 per cent toluol. In making this substrate whites of eggs were repeatedly strained through several thicknesses of cheesecloth. To five parts of egg white four parts of water were added and the egg white coagulated by heat while being stirred constantly. One part of toluol was added and the mass stirred to uniform consistency. This made a very finely divided product, of 50 per cent egg white (moist weight), which could be readily pipetted.

In the experiments on peptic and tryptic digestion the digests were made up to contain 12.5 c. c. of brei and 20 c. c. of coagulated egg white per 50 c. c. total. The approximate pH value of each digest was determined by paper indicators. For peptic digestion 0.2 N hydrochloric acid was added until the point was reached where congo red was just turned blue, a pH of about 3. In 50 c. c. digests about 15 c. c. hydrochloric acid were required. For tryptic and ereptic digestion tests 0.2 N sodium carbonate was added until phenolphthalein gave the first pinkish tint, at a pH of about 8.4. In the alkaline digests 2 to 4 c. c. of toluol were added in addition to that contained in the brei and egg white to prevent any bacterial action. Casein was chosen as substrate for ereptic digestion, since this protein is readily split by erepsin, while most other native proteins, such as egg albumin, are not. In the ereptic digestion tests 2 grams of powdered casein were used per 50 c. c. digests.

The progress of digestion was determined for pepsin, trypsin, and erepsin in terms of both the initial cleavage rate (tyrosine production), as shown by the colorimetric method of Folin and Denis (1912), and the amino acid production by the Sorenson formol titration method. The rate of digestion by the carbohydrate-splitting enzymes was determined in terms of the reducing power in milligrams of glucose per c. c. digest by Benedict's micro method for quantitative determination of sugar. In studying the rate of starch digestion the iodine test was also employed. Careful controls were made by the use of boiled extracts.

RESULTS AND DISCUSSION

REACTION IN THE DIGESTIVE TRACT

The reaction in the stomach and intestine was found to be exceedingly variable even among the animals of the same species, apparently depending upon the functional state of the organ. In the stomachs of all groups of poikilothermal vertebrates the reaction varied from about neutrality to an acidity sufficient to turn congo red purple, a pH of about 4. Generally the acidity was higher when the stomach contained food, subsiding to near neutrality when empty. The greatest acidity was observed in a bull snake, the stomach of which contained the remains of two mice, still largely intact, which had been devoured two days before killing. Here the hydrogen ion concentration was almost pH 3, while no acidity could be demonstrated in the stomach of a bull snake that had been fasting. In the stomachs of garter snakes that had swallowed frogs one to three hours before being opened a similar region of acidity was observed around the frogs. These findings agree with the early statements relating to fish. Tiedemann and Gmelin (1827) and Decker (1887) observed that contents of full stomachs of fish would always redden blue litmus, while the reaction at other times was neutral, slightly acid, or even very slightly alkaline.

The contents of the intestine also exhibited similar reaction in different classes of vertebrates. The reaction was in most cases about neutral, sometimes deviating to the acid side and sometimes to the alkaline, more frequently being slightly alkaline. The highest alkalinity, pH 8 to pH 8.4, was frequently observed in the small intestine of turtles. In the carp, which has no stomach but a long, comparatively undifferentiated alimentary canal, the reaction was in most cases slightly alkaline or neutral, though occasionally slightly acid. Variations in reaction of different parts of the tract of this fish were common. Acid reaction was observed most frequently in the posterior end of the intestine. Such acidity may be due to bacterial fermentation, which would perhaps take place to the greatest extent in this region, since it contains food materials that have remained longest in the intestine. It may be that the carp, an animal of rather sluggish habits, which stuffs its entire alimentary canal with vegetation, muddy algæ, minute insect larvæ, etc., depends more or less upon bacterial action as a material aid in the digestion of its food.

PEPTIC DIGESTION

ESOPHAGUS

Extracts of the esophageal mucosa of the pickerel, snapping turtle, and bull snake produced no increase in tyrosine or amino acid when allowed to act upon coagulated egg white at a pH of 3 for eight days. Absence of pepsin from the esophagus of these is in agreement with the known facts of their histological structure. Oppel (1897) cited observations of different workers upon numerous species of fishes, including the pickerel, and made the generalization that no glands are present in the esophagus of fishes. In sturgeons, however, gastric glands extend up into the esophagus (Kingsley 1917). In the amphibians glands are known to exist in the esophagus of *Proteus anguineus*, *Necturus maculosus*, and Rana, occurring most abundantly in the region of the esophagus nearest the stomach (Oppel, 1897).

Among the reptiles glands have not been found in the esophagus of Sauria and Ophidia, but have been described in the lower portion of the esophagus of certain Chelonia and Crocodilia (Oppel, 1897).

Decker (1887), using the disappearance of fibrin in dilute hydrochloric-acid extract as his criterion of peptic digestion, reported "peptic digestion" in the esophagus of fishes as of general occurrence. Biedermann (1911) believed that Decker mistook the simple action of acid upon fibrin for peptic digestion. It may be that Decker failed to thoroughly clean the esophagus from pepsin-laden fluids backing up from the stomach. It seems to the writer also possible that what Decker thought was peptic digestion may have been digestion by autolytic enzymes, which act in sufficiently dilute acid but are practically inhibited at a hydrogen-ion concentration of a pH 3 to 2.5, at which pepsin acts most rapidly. Observations that have been reported of small fishes digesting within the esophagus of larger fishes (such as those reported by Spallanzani, 1785) probably indicate merely digestion by gastric juice flowing forward into the esophagus.

STOMACH

Table 1 is a comparative record of results obtained for the rate of peptic digestion upon coagulated egg albumin by extracts from representatives of different classes of vertebrates. Increase of tyrosine is taken as the chief criterion for initial cleavage. While amino-acid production in gastric digestion is too small to be measured with any high degree of accuracy, it is interesting to note that there is slight increase in amino acid in each digest and to compare the amount produced here with that produced in tryptic and ereptic digestion (Tables 3 to 6).

TABLE 1.—*Rate of peptic digestion in different groups of vertebrates*

[Parallel digests with boiled extracts were run for each animal. Only two controls are included in the table to save space, since all controls produced no tyrosine or amino acid. Room temperature averaged 23 to 26° C. Each digest consisted of the following proportions: 12.5 c. c. extract of stomach mucosa (except carp)+20 c. c. coagulated egg albumin+0.2 N HCL (about 15 c. c.) to approximately pH 3 to 50 c. c. total]

Animal	Number of tests	Milligrams tyrosine in 2 c. c. filtrate						C. c. 0.2 N amino acid in 10 c. c. filtrate		
		Days					Net gain, 8 days	Days		Net gain, 8 days
		0	1	2	4	8		0	8	
Fish:										
Carp control	3	0.087	0.087	0.087	0.087	0.087	0.000	0.100	0.100	0.000
Alimentary tract to first bend	3	.079	.119	.120	.120	.120	.041	.083	.133	.050
Posterior to first bend	2	.067	.125	144	.144	.150	.083	.125	.225	.100
Bluegill control	1	.154	.154	.154	.154	.154	.000	.100	.100	.000
experiment	1	.154	.418	.424	-------	.467	.313	.100	.450	.350
Crappie do.	1	.143	.400	.446	.446	.472	.329	.150	.500	.350
Pickerel do.	3	.094	.364	.422	.440	.452	.358	.116	.300	.183
White bass do.	2	.175	-------	.349	.396	.456	.281	.050	.200	.150
Amphibia: Necturus do.	2	.131	.435	.444	.462	.468	.337	.125	.350	.225
Reptile:										
Painted turtle do.	1	.091	.461	.476	.493	.505	.414	.100	.400	.300
Snapping turtle do.	2	.088	.428	.456	.470	.526	.438	.100	.325	.225
Bull snake do.	2	.122	.478	-------	.506	.506	.384	.100	.525	.425
Mammal: Dog do.	1	.222	.467	-------	.500	.500	.278	.200	.500	.300

With the exception of the carp (the only animal used having no well-formed stomach) all the animals showed a remarkably uniform rate of digestion. Since the carp differs so widely in anatomical structure and activity, it will be discussed by itself later. Individual variations among different animals of the same species were not great. With the exception of the carp, also, there seems to be little change in the rate of peptic digestion correlated with differences in food habits. Among the fishes the pickerel, which feeds almost entirely upon fishes, does not show an outstandingly higher rate of peptic digestion than the bluegill and crappie, the diet of which includes a larger proportion of vegetable matter, more insects, and small crustaceans. In 18 bluegills examined Pearse (1921) found that plants and algæ constituted 24 per cent of the total volume of food in the digestive tracts.

Coagulated egg albumin seems to be equally well digested by the enzymes of fish, amphibians, reptiles, and mammals. Several workers, however, have reported that coagulated egg albumin is only very slowly digested by fish pepsin (Decker, 1887, for pike, cited by Biedermann; Yung, 1899, for selachians; and Bodansky and Rose, 1922). Bodansky and Rose (1922) stated that the slow digestion of coagulated egg albumin by fish pepsin was not entirely due to the small surface exposed, for finely divided albumin was not digested with an appreciably greater rapidity. ''Furthermore, a commercial pepsin solution capable of producing an effect on fish meat similar in extent to that exerted by fish pepsin digested coagulated egg albumin quite readily.'' Their criterion for the extent of digestion of the coagulated egg albumin, or just how finely the egg albumin was divided, was not stated. Obviously a comparison between the activity of extracts of gastric mucosa and the activity of commercial pepsin would not be as satisfactory as the comparison between the activity of uniformly prepared extracts from the gastric mucosa of the animals.

The only previous attempt to compare the rate of digestion in representatives of different classes of poikilothermal vertebrates is that of Riddle (1909), who tried to determine the rate of gastric digestion in living fishes, amphibians, and reptiles by comparing the rate of disappearance of coagulated egg white in Mett's tubes introduced into the stomach. Riddle concluded that there was a progressive loss in digestive power in ascending the vertebrate scale from fishes to reptiles. However, in view of the extremely wide differences which Riddle obtained in the same species under the same conditions, and the lack of fairly constant results for each class of animals studied, such a conclusion seems highly speculative, and the method used an unsatisfactory one for reliable comparisons. The results obtained in the present investigation definitely show that in evolution from fishes to reptiles there has been no loss in digestive power. On the contrary, the digestive power in the reptiles used, if different, seems to be a trifle greater than in other groups. The results in Table 1 indicate that in poikilothermal vertebrates with well-developed stomachs and in the dog [1] equal amounts of stomach mucosa possess approximately the same digestive power.

The carp, from which outstandingly different results were obtained, differs in anatomical structure from fishes of other groups in the absence of a glandular stomach and in the presence of an extensive hepatopancreas. The bile duct enters the alimentary tract immediately behind the pharynx, and the entire alimentary canal, which is about 4 feet in length in a carp weighing 2 kilograms, has the appearance and histological structure of an intestine. It is wholly devoid of gastric glands (Oppel, 1897).

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[1] In preparing the extract from gastric mucosa of the dog a larger proportion of the pyloric region than of the cardiac region was used, which may account for the slightly lower rate of tyrosine production in this animal.

In digests with extracts from the anterior segment and with those from the entire posterior part of the alimentary canal production of tyrosine was very small, and it seems doubtful whether it was peptic in nature. Since practically all of the increase in tyrosine occurred during the early part of experiments, the apparent peptic digestion in the carp may have been due to the action of autolytic enzymes for a short time before they were entirely inhibited by the hydrogen-ion concentration of pH 3, which was approximated by the use of congo red indicator paper. In studies on autolysis of liver and kidney, Bradley (1922) observed that the maximum digestion took place at pH 4.0 to 4.5 (obtained by adding 25 to 40 c. c. of 0.2 N hydrochloric acid per 250 c. c. of brei), and that digestion by autolytic enzymes was practically at a standstill at a pH of 3 to 2.5 (obtained by the addition of 75 to 100 c. c. of 0.2 N hydrochloric acid per 250 c. c. of brei). In the writer's experiments about 15 c. c. of 0.2 N hydrochloric acid were added per 50 c. c. digests, which would be equivalent to 75 c. c. for 250 c. c. of brei. It would seem possible, therefore, should autolytic enzymes of similar character to those of liver and kidney be present in the mucosa of the digestive tract, that they might be able to exert a slight effect before their complete inhibition. That the digestion by extracts from the alimentary tract of the carp was not peptic seems almost certain from the fact that in nearly all the digests (cf. also Table 2) no digestion to an appreciable extent took place after the first day, though plenty of egg albumin was present and conditions were near the optimum for peptic digestion.

Table 2 shows differences in rates of peptic digestion at 37° C. and at room temperature. Except for differences in temperature the tests were made exactly as in Table 1. With the exception of the pickerel, where no appreciable difference is shown in the rate of digestion at 24 and 37° C., peptic digestion was uniformly more rapid at 37° than at room temperature. Moreover, about the same proportionate increase in tyrosine (initial cleavage) at 37° C. over that at room temperature was produced in amphibians, reptiles, and the mammals.

TABLE 2.—*Peptic digestion at room temperature and at 37° C.*

[Digests were prepared exactly as in Table 1, with initial pH 3]

Animal	Temperature, in degrees	Milligrams tyrosine in 2 c. c. filtrate						C. c. 0.2 N amino acid in 10 c. c. filtrate		
		Days					Net gain, 8 days	Days		Net gain, 8 days
		0	1	2	4	8		0	8	
Fish:										
Carp	23	0.078	0.118	0.118	0.118	0.118	0.040	0.05	0.15	0.10
	37	.078	.100	.105	.105	.111	.033	.05	.15	.10
Pickerel	24	.085	.340	.417	.441	.441	.356	.10	.30	.20
	37	.085	.339	.374	.431	.431	.346	.10	.25	.15
Amphibia: Necturus	23	.182	.435	-------	.465	.476	.294	.15	.45	.30
	37	.160	.500	-------	.500	.500	.340	.15	.55	.40
Reptile:										
Snapping turtle	23	.101	.428	.453	.463	.463	.362	.05	.25	.20
	37	.101	.470	.538	.541	.541	.440	.05	.30	.25
Bull snake No. 1	23	.143	.500	.535	.535	.535	.392	.10	.55	.45
	37	.160	.527	.582	.582	.582	.422	.10	.65	.55
Bull snake No. 2	23	.100	.455	-------	.476	.476	.376	.10	.50	.40
	37	.089	.500	-------	.556	.556	.467	.10	.60	.50
Mammal: Dog	23	.222	.467	-------	.500	.500	.278	.20	.50	.30
	37	.222	.500	.547	.547	.556	.334	.20	.60	.40

TRYPTIC DIGESTION

Tables 3 and 4 show data obtained for tryptic digestion by extracts from the pancreas in different animals and from the hepatopancreas of the carp. The results are typical for tryptic digestion, a comparatively large amount of amino acids being split off in addition to a large amount of tyrosine, while in peptic digestion amino acids were split off only to a very slight extent (cf. Tables 1 and 2). Since the experiments were carried on in definitely alkaline media having an initial pH above 8, peptic and autolytic digestion would be practically ruled out. That the digestion of egg white by extracts from the pancreas was truly tryptic was further shown in separate tests by the fact that as the hydrogen-ion concentration was increased to pH 7 and higher the rate of digestion rapidly decreased, and vice versa.

Table 3.—*Tryptic digestion in different groups of vertebrates*

[Except for Necturus [1] and bull snake,[2] digests were made up of the proportion: 12.5 c. c. pancreas extract+20 c. c. coagulated egg albumin+0.2 N sodium carbonate to approximately pH 8.4+toluol (10 per cent of total)+distilled water to 50 c. c. total volume]

Animal	Average temperature in degrees	Milligrams tyrosine in 2 c. c. filtrate						C. c. 0.2 N amino acid in 10 c. c. filtrate					
		Days					Net gain	Days					Net gain
		0	1	2	4	8		0	1	2	4	8	
Carp	23	0.143	0.182	0.200	0.229	0.250	0.107	0.30	0.45	0.55	0.65	0.80	0.50
Pickerel	23	.317	.431	.455	.591	.650	.333	.35	.50	.90	1.00	1.10	.75
Painted turtle	25	.294	.625	.714	------	.884	.590	.35	------	------	------	2.25	1.90
Snapping turtle	26	.173	.527	.637	.909	.966	.793	.25	------	1.35	------	2.10	1.85
Dog	23	.313	.645	.704	.681	.681	.368	.70	1.70	1.85	2.00	2.30	1.60
Necturus	23	.190	.303	------	.400	.435	.245	.30	.50	------	.75	.90	.60
Bull snake	21	.148	.334	------	.385	.435	.287	.35	.65	------	1.00	1.10	.75

[1] Necturus digest contained only 5 c. c. of extract, thus representing only 40 per cent of the amount of pancreas used in the first five tests.

[2] Bull snake digest contained only 4 c. c. of extract, representing about 32 per cent of the amount of pancreas used in the first five tests. It was necessary to work with a much smaller quantity in Necturus and snake because of the very small amount of pancreas obtainable.

Table 4.—*Tryptic digestion at room temperature and at 37° C.*

[Digests were prepared exactly as in Table 3, with an initial pH approximately 8.4]

Animal	Temperature in degrees	Milligrams tyrosine in 2 c. c. filtrate						C. c. 0.2 N amino acid in 10 c. c. filtrate					
		Days					Net gain	Days					Net gain
		0	1	2	4	8		0	1	2	4	8	
Carp (hepatopancreas)	23	0.100	0.138	0.167	0.182	0.182	0.082	0.20	0.30	0.40	0.50	0.55	0.35
	37	.100	.160	.211	.250	.345	.245	.20	.35	.50	.65	.95	.75
Do	23	.143	.182	.200	.229	.250	.107	.30	.45	.55	.65	.80	.50
	37	.143	.211	.235	.385	.455	.312	.30	.55	.65	.90	1.10	.80
Dog (pancreas)	23	.313	.645	.704	.681	.681	.368	.70	1.70	1.85	2.00	2.30	1.60
	37	.313	.695	.741	.695	.695	.382	.70	2.10	2.30	2.40	2.40	1.70
Necturus (pancreas)[1]	23	.190	.303	------	.400	.435	.245	.30	.50	------	.75	.90	.60
	37	.160	.476	------	.527	.527	.367	.30	.70	------	1.10	1.40	1.10

[1] Necturus digest contained only 5 c. c. of extract.

In the carp the rate of tryptic digestion for a given amount of hepatopancreas was low as compared with that in the true pancreas, such as is found in Necturus, turtle, or dog. However, if the relative size of the hepatopancreas is taken into consideration, this organ would probably contain an even greater amount of trypsin for the size of the animal than does a typical pancreas in other animals. The pancreas of the pickerel, like that in many other teleosts, is a diffused organ, so that the pancreatic tissue used was more or less mixed with fatty and connective tissue. The well-defined pancreas in the amphibians and reptiles studied gave a high rate of tryptic activity. Since the amount of pancreas available from bull snakes and Necturus was very small, it was necessary to use less than half the proportion of tissue in the digests for them. Considering the comparatively rapid rate of amino acid and tyrosine production in the pancreatic digests of these two animals, it is probable that the capacity of a given weight of pancreas in the bull snake and Necturus for tryptic digestion is equal to that of the turtles and the dog.

From Table 4, showing the results of parallel experiments at room temperature and at 37° C., it may be seen that tryptic digestion was much more rapid at 37° than at 23° C. for all the animals tested. The higher temperature seemed to produce a slightly greater rate of increase in tryptic digestion in the carp than in Necturus and the dog.

Experiments were carried on in the same way as with the pancreas, using extracts of mucosa from different regions of the digestive tract to find out whether or not trypsin is secreted in other organs than the pancreas. No tryptic digestion was obtained in extracts from the stomach mucosa of various animals, including the pickerel, white bass, Necturus, and snapping turtle, nor from the intestinal mucosa of Necturus, turtle, bull snake, and dog. There was slight evidence of tryptic digestion (increase in tyrosine and amino acid) in the intestine of the pickerel and in the caeca of the crappie. Repeated experiments using extracts from the mucosa of the anterior, middle, and posterior regions of the alimentary tract of the carp all showed no increase in amino acid or tyrosine in 8 days. Bile from the carp also produced no digestion of coagulated egg albumin in digests at a pH of approximately 8.4, 7, and 3. Homburger (1877, cited by Biedermann), however, reported that in carp aqueous extracts of hepatopancreas, intestinal mucosa, and bile itself digested fibrin in neutral or alkaline but not in acid solution. Krukenberg in the same year (1877, cited by Biedermann) reported the indubitable existence of trypsin formation in the intestinal mucosa of many teleosts and especially in the carp. If true trypsin were secreted in the intestinal mucosa of the carp, digests made up in exactly the same way as those which show strong tryptic digestion for the pancreas should likewise produce tyrosine and amino acid. In the pickerel, where some tryptic digestion by intestinal mucosa extracts was observed, the amount of amino acid and tyrosine was exceedingly small as compared with digestion by the pancreatic extracts. It seems probable, therefore, that the intestinal mucosa plays no part of digestive importance in the secretion of trypsin in animals having a well-defined pancreas, and that in fishes with a diffused pancreas a trace of tryptic digestion by extracts from the intestinal wall may be due to small ramifications of pancreatic tissue embedded within the wall.

EREPTIC DIGESTION

Up to the present time the general occurrence of erepsin in the intestinal mucosa of lower vertebrates has not been demonstrated. In fact, most of the investigations that have been made of digestive enzymes in lower vertebrates were made before the discovery of erepsin by Conheim (1901). The only record of ereptic digestion in poikilothermal vertebrates which the writer has been able to find was a brief statement by Krüger (1905) that an extract could be obtained from the small intestine of *Gadus morrhua*, which showed characteristic erepsin-like activity.

Tables 5 and 6 show the results obtained for ereptic digestion by extracts of intestinal mucosa from representatives of different groups of vertebrates. In Table 6 parallel experiments with digests at room temperature and at 37° were made. In Table 5 all experiments were made at room temperature. Since erepsin digests casein but not other native proteins, with the exception of histones and protamines, casein was used as a substrate. The digests were all made alkaline with 0.2 N sodium carbonate to an initial pH as low as 8.4, thus preventing action by autolytic enzymes and pepsin. Parallel digests with coagulated egg albumin were used as controls against any tryptic digestion. It will be noted that in this case, as in tryptic action, the amino acid increase was comparatively high.

The data presented in Table 5 show that erepsin is present in the intestinal mucosa of the representatives of all classes of poikilothermal vertebrates in as great an abundance as in the intestinal mucosa of the dog. In the carp ereptic digestion was greatest in extracts from the anterior end of the alimentary tract, gradually decreasing posteriorly. In the pickerel a definite though small increase in both amino acid and tyrosine in the control digest probably indicates a trace of tryptic digestion. This may have been a factor in the high rate of casein cleavage for the pickerel. Where the animal possessed a well defined small and large intestine, digests using extracts of mucosa from the small intestine only are included in the tables. Extracts from the mucosa of the large intestine of the snapping turtle, an animal in which the large and the small intestine are clearly defined, also produced a high rate of ereptic digestion. Erepsin has likewise been reported present in considerable quantity in the large as well as small intestine of the rabbit (Glaessner, 1910).

TABLE 5.—*Ereptic digestion in different groups of vertebrates*

[Digests = 12.5 c. c. extract of intestinal mucosa + 2 grams casein + distilled water + 0.2 N sodium carbonate to approximately pH 8.4 + toluol (10 per cent of total) + distilled water to 50 c. c. Controls have 20 c. c. coagulated egg albumin substituted for casein]

Animal		Average temperature in degrees	Milligrams tyrosine in 2 c. c. filtrate						C. c. 0.2 N amino acid in 10 c. c. filtrate					
			Days					Net gain	Days					Net gain
			0	1	2	4	8		0	1	2	4	8	
Fish:														
Carp, to first bend of intestine	control	22	0. 087	0. 087	0. 087	0. 087	0. 087	0. 000	0. 10	0. 15	0. 15	0. 15	0. 15	0. 05
	experiment	22	. 097	. 238	. 271	. 402	. 513	. 416	. 10	. 35	. 50	. 70	1. 10	1. 00
Carp, middle of intestine	control	22	. 067	. 067	. 067	. 067	. 067	. 000	. 15	. 15	. 15	. 15	. 15	. 00
	experiment	22	. 073	. 200	. 205	. 285	. 334	. 261	. 15	. 20	. 35	. 40	. 65	. 50
Carp, posterior region of intestine	control	22	. 057	. 057	. 057	. 057	. 057	. 000	. 10	. 10	. 10	. 10	. 10	. 00
	experiment	22	. 057	. 190	. 267	. 254	315	. 258	. 10	------	. 25	------	. 50	. 40
Pickerel	control	23	. 073	. 073	. 073	. 080	. 111	. 038	. 15	. 15	------	------	. 30	. 15
	experiment	23	. 067	. 200	. 325	. 541	. 909	. 842	. 10	. 10	. 35	. 65	1. 20	1. 10
	experiment	23	. 057	. 173	. 313	. 455	. 752	. 695	. 15	------	. 40	. 70	1. 30	1. 15
Amphibia: Necturus	control	21	. 057	. 057	. 057	. 057	. 057	. 000	. 10	. 10	. 10	. 10	. 10	. 00
	experiment	21	. 059	. 182	. 235	. 334	. 476	. 317	. 10	------	. 50	. 80	1. 00	. 90
	experiment	23	. 074	. 196	-------	. 313	. 385	. 311	. 10	. 40	------	. 80	1. 00	. 90
Reptile:														
Snapping turtle	control	26	. 100	. 105	. 105	. 105	. 105	. 005	. 15	------	. 15	------	. 20	. 05
	experiment	26	. 173	. 532	. 633	. 892	. 985	. 812	. 20	------	. 70	------	1. 35	1. 15
	experiment	23	. 156	. 524	. 851	. 943	. 980	. 824	. 25	. 72	. 95	1. 10	1. 70	1. 45
Bull snake	control	21	. 057	. 057	. 057	. 057	. 057	. 000	. 10	------	. 10	. 10	. 10	. 00
	experiment	21	. 057	. 103	. 125	. 200	. 313	. 256	. 10	------	. 30	. 40	. 70	. 60
	experiment	23	. 071	-------	-------	. 294	. 371	. 300	. 10	------	------	. 50	. 70	. 60
Mammal: Dog	control	23	. 112	. 112	. 112	. 112	. 112	. 000	. 30	. 30	. 30	. 30	. 30	. 00
	experiment	23	. 112	. 222	. 282	. 334	. 392	. 280	. 30	. 45	. 55	. 80	1. 30	1. 00

TABLE 6.—*Ereptic digestion at room temperature and at 37° C.*

[Digests were prepared exactly as in Table 5, with an initial pH approximately 8.4]

Animal	Temperature in degrees	Milligrams tyrosine in 2 c. c. filtrate						C. c. 0.2 N amino acid in 10 c. c. filtrate					
		Days					Net gain	Days					Net gain
		0	1	2	4	8		0	1	2	4	8	
Fish:													
Carp	22	0. 073	0. 200	0. 205	0. 285	0. 334	0. 261	0. 15	0. 20	0. 35	0. 40	0. 65	0. 50
	37	. 073	. 222	. 229	. 417	. 448	. 375	. 15	. 30	------	. 75	1. 05	. 90
Pickerel	23	. 057	. 163	. 313	. 455	. 752	. 695	. 15	------	. 40	. 70	1. 30	1. 15
	37	. 057	. 371	. 444	. 667	. 896	. 839	. 15	------	. 70	1. 25	1. 50	1. 40
Amphibia: Necturus	23	. 074	. 196	-------	. 313	. 385	. 311	. 10	. 40	------	. 80	1. 00	. 90
	37	. 074	. 334	-------	. 500	. 556	. 482	. 10	. 75	------	1. 20	1. 45	1. 35
Reptile:													
Snapping turtle	23	. 089	. 149	. 209	. 325	. 508	. 419	. 20	------	. 30	. 50	1. 00	. 80
	37	. 089	. 204	. 385	. 667	. 851	. 762	. 20	------	. 60	1. 05	1. 40	1. 20
Bull snake	23	. 071	-------	-------	. 294	. 371	. 300	. 10	------	------	. 50	. 70	. 60
	37	. 071	-------	-------	. 556	. 667	. 596	. 10	------	------	1. 10	1. 50	1. 40
Do	21	. 057	. 103	. 125	. 200	. 313	. 256	. 10	------	. 30	. 40	. 70	. 60
	37	. 057	. 154	. 211	. 357	. 541	. 484	. 10	------	. 45	. 70	1. 00	. 90
Mammal: Dog	23	. 112	. 222	. 282	. 334	. 392	. 280	. 30	. 45	. 55	. 80	1. 30	1. 00
	37	. 112	. 267	. 385	. 500	. 654	. 542	. 30	. 75	1. 00	1. 50	1. 80	1. 50

The series of parallel experiments at room temperature and at 37° C. shows that in all cases the rate of digestion was much more rapid at 37° C. than at 19 to 23° C. For all the animals the increase in rate of digestion at the higher temperature was in about the same proportion. It may be concluded from these experiments that erepsin like that occurring in the intestinal mucosa of mammals occurs in the intestinal mucosa of fishes, amphibians, and reptiles.

CARBOHYDRATE-SPLITTING ENZYMES

AMYLASE

The results of all the digestion tests with carbohydrate-splitting enzymes are given in terms of the reducing power in milligrams of glucose per c. c. of digest. Table 7 shows the rate of starch digestion by extracts of esophageal and stomach mucosa from pickerel, bull snake, and snapping turtle, and of stomach mucosa from the crappie. While slight hydrolysis of starch took place in all these experiments, especially in the esophagus of the pickerel, its rate was too low to indicate the presence of amylase in sufficient quantities to be of digestive significance.

Table 7.—*Amylase*

[50 c. c. digests were used containing boiled starch to 1 per cent and toluol to 5 per cent of total volume. Controls contained boiled extracts]

Description		C. c. of extract	Milligrams glucose per c. c. digest				Net gain			Iodine test at 2 or 4 days
			Days				Days			
			0	1	2	4	1	2	4	
Esophagus:										
Pickerel No. 1	control	2	1.08	1.08	1.09	1.11	0.00	0.01	0.03	Blue.
	experiment	2	1.08	1.79	2.63	3.12	.71	1.55	2.04	Brick red.
Pickerel No. 2	control	2	1.06		1.06		.00	.00		Blue.
	experiment	2	1.06		2.50			1.44		Do.
Pickerel No. 3	control	2	1.03		1.04			.01		Do.
	experiment	2	1.03		1.21			.18		Do.
Bull snake	control	6	1.02		1.02	1.02		.00	.00	Do.
	experiment	6	1.02		1.11	1.16		.09	.14	Do.
Snapping turtle	control	2	1.15	1.15		1.15	.00		.00	Do.
	experiment	2	1.15	1.34		1.82	.19		.67	Do.
Stomach:										
Crappie	control	2	1.20	1.20	1.20	1.20	.00	.00	.00	Do.
	experiment	2	1.20	1.43	1.59	2.17	.23	.39	.97	Do.
Pickerel No. 1	control	2	1.11	1.11	1.11	1.11	.00	.00	.00	Do.
	experiment	2	1.11	1.17	1.30	1.47	.06	.19	.36	Do.
Pickerel No. 2	control	2	1.03		1.03			.00		Do.
	experiment	2	1.03		1.34			.31		Do.
Bull snake	control	2	1.02		1.02	1.02		.00	.00	Do.
	experiment	2	1.02		1.09	1.15		.07	.13	Do.
Snapping turtle	control	2	1.15	1.15		1.15	.00		.00	Do.
	experiment	2	1.15	1.34		1.73	.19		.58	Do.

In the intestinal mucosa of representative fishes, amphibians, and reptiles, and in the caeca of the crappie (Table 8) a considerably larger amount of amylase was present. However, 2 c. c. of extract did not convert all of 50 c. c. of 1 per cent cooked starch in four days, a much slower rate than that of the extremely rapid digestion by extract from pancreatic tissues. These data indicate the presence of a greater amount of amylase in the intestinal mucosa of the animals whose diet includes a considerable amount of vegetable matter, as the carp and turtle, and a less amount in animals such as the bull snake, whose diet consists almost wholly of animal food.

TABLE 8.—*Amylase*

[50 c. c. digests were used containing boiled starch to 1 per cent and toluol to 5 per cent of total volume. Controls contain boiled extract. In iodine test, — = blue, no color change; + = some color change (reddish or brownish); ++ = colorless, no starch.]

Description		C. c. of extract	Milligrams glucose per c. c. digest				Net gain			Iodine test at end of experiment
			Days				Days			
			0	1	2	4	1	2	4	
Intestine:										
Carp[1]—										
Section 1	control	2	1.11	1.11	1.11	1.11	0.00	0.00	0.00	—
Section 1	experiment	2	1.11	2.44	3.85	4.76	1.33	2.74	3.65	+
Section 2	do	2	1.11	2.00	3.12	4.35	.89	2.01	3.24	+
Section 3	do	2	1.11	1.36	2.38	3.33	.25	1.27	2.22	+
Section 4	do	2	1.11	--------	2.94	3.23	--------	1.83	2.01	+
Carp, middle of intestine	control	2	1.15	1.15	1.15	1.15	.00	.00	.00	—
	experiment	2	1.15	2.38	2.86	3.57	1.23	1.71	2.42	+
Sucker, anterior third of intestine	control	2	1.11	1.11	1.11	1.11	.00	.00	.00	—
	experiment	2	1.11	1.47	2.17	2.78	.36	1.06	1.67	+
Necturus	control	2	1.08	--------	1.08	--------	--------	.00	--------	—
	experiment	2	1.08	--------	2.56	--------	--------	1.48	--------	+
Bull snake	control	6	1.02	--------	1.02	1.02	--------	.00	--------	—
	experiment	6	1.02	--------	1.39	2.08	--------	.37	1.06	+
Snapping turtle	control	2	1.00	1.00	1.00	1.00	.00	.00	.00	—
	experiment	2	1.00	2.38	3.33	4.00	1.38	2.33	3.00	+
	control	2	1.11	1.11	--------	1.11	.00	.00	.00	—
	experiment	2	1.11	2.86	--------	5.55	1.75	--------	4.44	+
Caeca: Crappie	control	1	1.36	1.36	1.36	1.36	.00	.00	.00	—
	experiment	1	1.36	2.27	2.78	3.85	.91	1.42	2.49	+

[1] Equal length sections, anterior to posterior, of entire alimentary tract.

With the exception of the pickerel, in which the pancreas is not well defined, all pancreatic digests produced exceedingly rapid digestion (Table 9). In nearly all cases 2 c. c. of extract converted 50 c. c. of 1 per cent starch solution to reducing sugar within one day, and the greater part of it was reduced within a few minutes or hours. The iodine tests likewise indicated rapid disappearance of the starch, generally becoming colorless within a few hours. With 0.5 c. c. of extract of carp hepatopancreas in 50 c. c. of 1 per cent starch, the iodine test indicated the total disappearance of starch, and Benedict's sugar test indicated an increase in reducing sugar of 5.57 to 6.17 milligrams per cubic centimeter in four hours (Table 10). With the same amount of extract of turtle pancreas per 50 c. c. digest the iodine starch test was almost colorless, and the reducing sugar was increased 5.15 milligrams per cubic centimeter in one hour (Table 11). In order to determine if amylase from the turtle's pancreas acted upon starch more rapidly at 37° C. than at room temperature, 1 c. c. of extract diluted 10 times was used in 50 c. c. of 1 per cent solution, which would be the equivalent of extract from 1 gram of tissue to 4,000 c. c. of 1 per cent starch (Table 12). In one hour the digest at 24° C. had gained 2.01 milligrams of glucose per cubic centimeter, while the other at 37° C. had gained 2.22 milligrams of glucose per cubic centimeter, indicating more rapid digestion at 37° C.

In comparing starch digestion in the carp and the pickerel, it should be noted that the carp, which is largely a vegeterian, possesses amylase in tremendous amounts in the hepatopancreas and to a less extent throughout the intestinal mucosa. The pickerel, on the contrary, which ordinarily does not eat plant foods except what it may take in "second hand" within the digestive tract of its prey, possesses only a negligible quantity of amylase, having little in the pancreas, esophagus, intestine, and practically none in the stomach.

TABLE 9.—*Amylase*

[50 c. c. digests were used containing boiled starch to 1 per cent and toluol to 5 per cent of total volume. Controls contain boiled extract. In iodine test, − = blue, no color change; + = some color change (reddish or brownish); ++ = colorless]

Description		C. c. of extract	Milligrams glucose per c. c. digest				Net gain			Iodine test at end of experiment
			Days				Days			
			0	1	2	4	1	2	4	
Pancreas:										
Pickerel No. 1	control	2	1.17	1.17	1.17	1.17	0.00	0.00	0.00	−
	experiment	2	1.17	2.08	2.38	2.94	.91	1.21	1.77	+
Pickerel No. 2	control	2	1.17	--------	1.17	--------	--------	.00	--------	−
	experiment	2	1.17	--------	2.56	--------	--------	1.39	--------	+
Pickerel No. 3	control	2	1.19	1.19	1.19	1.19	.00	.00	.00	−
	experiment	2	1.19	1.92	2.08	2.78	.73	.89	1.59	+
Pickerel No. 4	control	2	1.19	--------	1.19	--------	--------	.00	--------	−
	experiment	2	1.19	--------	4.17	--------	--------	2.98	--------	+
Hepatopancreas:										
Carp No. 1	control	2	1.11	1.11	1.11	--------	.00	.00	--------	−
	experiment	2	1.11	10.00	10.00	--------	8.89	8.89	--------	++(1 day).
Carp No. 2	control	2	1.11	1.11	1.11	--------	.00	.00	--------	−
	experiment	2	1.11	11.10	11.10	--------	9.99	9.99	--------	++(1 day).
Sucker	control	1	1.20	1.20	1.20	--------	.00	.00	--------	−
	experiment	1	1.20	6.25	6.25	--------	5.05	5.05	--------	++(1 day).
Pancreas:										
Necturus	control	2	1.11	1.11	--------	--------	.00	--------	--------	−
	experiment	2	1.11	6.25	--------	--------	5.14	--------	--------	++(1 day).
Bull snake	control	2	1.09	1.09	1.09	--------	.00	.00	--------	−
	experiment	2	1.09	5.88	6.25	--------	4.79	5.16	--------	++

TABLE 10.—*Amylase in hepatopancreas of carp*

[Digest=0.5 c. c. extract in 50 c. c. total (1 per cent starch, 5 per cent toluol). Control contained 0.5 c. c. boiled extract]

Description		Milligrams glucose per c. c. digest		Net gain in 4 hours	Iodine test in 4 hours
		Hours			
		0	4		
Carp No. 1	control	1.25	1.25	0.00	Blue.
	experiment 1	1.25	7.42	6.17	Colorless.
	experiment 2	1.25	7.42	6.17	Do.
Carp No. 2	control	1.10	1.10	.00	Blue.
	experiment 1	1.10	6.67	5.57	Colorless.
	experiment 2	1.10	6.67	6.57	Do.

TABLE 11.—*Amylase in pancreas of snapping turtle*

[Digest=0.5 c. c. extract in 50 c. c. total (1 per cent starch, 5 per cent toluol)]

Description	Minutes						Net gain in 60 minutes
	0	5	10	15	30	60	
Milligrams glucose per cubic centimeter digest	1.11	2.86	4.00	5.00	5.55	6.25	5.14
Color iodine test	Blue.	Lighter blue.	Lavender.	----------	Very light blue.	Nearly colorless.	

TABLE 12.—*Amylase in pancreas of painted turtle*

[Digestion at 24° C. and at 37° C. The (25 per cent tissue) extract was diluted to one-tenth strength. Digests=1 c. c. diluted extract in 50 c. c. total (1 per cent starch, 5 per cent toluol). Equivalent to the extract from 1 gram of pancreas to 4,000 c. c. 1 per cent starch]

Description	Minutes			Net gain in 60 minutes
	0	30	60	
Temperature 24° C.:				
Reducing power in milligrams glucose per cubic centimeter digest	1.11	2.08	3.12	2.01
Color of iodine test	Deep blue.	Blue.	Purplish.	
Temperature 37° C.:				
Reducing power in milligrams glucose per cubic centimeter digest	1.11	2.13	3.33	2.22
Color of iodine test	Deep blue.	Blue.	Purplish.	

INVERTING ENZYMES

Tables 13 and 14 show tests made for the presence of invertase. With the exception of the bluegill, the caeca of which were used, and the pickerel, of which the entire digestive tract was tested, investigation for invertase was limited to the intestine. In the carp different regions of the entire alimentary canal, which shows characteristics of an intestine, were tested. In the bluegill some invertase was found in both the caeca and the intestine. No invertase was found in the small intestine of Necturus, the bull snake, or the large intestine of the snapping turtle. It was present in a very small amount in the intestine of the pickerel. The carp, bluegill, and snapping turtle each possessed a relatively large amount of invertase. It is an interesting fact that these three animals include a considerable amount of vegetable food in their diet. The other three animals in which invertase was absent or present only as a slight trace feed almost wholly on animal food.

TABLE 13.—*Invertase*

[50 c. c. digests were used containing sucrose solution to 1 per cent and toluol to 5 per cent of total volume. Controls contain boiled extract]

Description		C. c. of extract	Milligrams glucose per c. c. digest				Net gain		
			Days				Days		
			0	1	2	4	1	2	4
Caeca: Bluegill	control	2	1.11	--------	1.11	1.11	0.00	0.00	0.00
	experiment	2	1.11	--------	1.96	2.63	--------	.85	1.52
Intestine:									
Bluegill	control	2	1.11	--------	1.11	1.11	--------	.00	.00
	experiment	2	1.11	--------	2.50	3.85	--------	1.39	2.74
Carp (entire tract in 4 sections)—									
Section 1	control	2	1.05	1.05	1.05	1.05	.00	.00	.00
Section 1	experiment	2	1.05	1.59	2.96	3.33	.54	1.51	2.28
Section 2	do	2	1.05	1.52	1.85	2.44	.47	.80	1.39
Section 3	do	2	1.05	1.41	1.67	2.22	.36	.62	1.17
Section 4	do	2	1.05	1.17	1.19	1.19	.12	.14	.14
Carp (middle of intestine)	control	2	1.10	1.10	1.10	1.10	.00	.00	.00
	experiment	2	1.10	1.52	2.00	2.50	.42	.90	1.40
Pickerel	control	2	1.08	--------	1.08	--------	--------	.00	--------
	experiment	2	1.08	--------	1.11	--------	--------	.03	--------
	control	2	1.15	1.15	1.15	1.15	.00	.00	.00
	experiment	2	1.15	1.36	1.47	2.00	.21	.32	.85
Necturus	control	2	1.05	--------	1.05	1.05	--------	.00	.00
	experiment	2	1.05	--------	1.05	1.05	--------	.00	.00
Snapping turtle	control	2	.95	.95	.95	.95	.00	.00	.00
	experiment	2	.95	1.06	1.15	1.49	.11	.20	.54
	control	2	1.11	1.11	--------	1.11	.00	--------	.00
	experiment	2	1.11	1.85	--------	3.85	.74	--------	2.74
Snapping turtle (large intestine)	control	2	1.04	1.04	--------	1.04	.00	--------	.00
	experiment	2	1.04	1.04	--------	1.04	.00	--------	.00
Bull snake	control	2	1.00	--------	1.00	1.00	.00	.00	.00
	experiment	2	1.00	--------	1.00	1.00	.00	.00	.00
	do	6	1.02	--------	1.02	1.02	.00	.00	.00

TABLE 14.—*Invertase. Entire alimentary tract of pickerel*

[50 c. c. digests were used containing sucrose solution to 1 per cent and toluol to 5 per cent of total volume. Controls contain boiled extract]

Description		C. c. of extract	Milligrams glucose per c. c. digest				Net gain		
			Days				Days		
			0	1	2	4	1	2	4
Esophagus	control	2	1.03	--------	1.03	--------	--------	0.00	--------
	experiment	2	1.03	--------	1.03	--------	--------	.00	--------
Stomach	control	2	1.15	1.15	1.15	1.16	0.00	.00	0.01(?)
	experiment	2	1.15	1.16	1.16	1.16	.00	.01	.01(?)
Do	control	2	1.08	1.08	1.08	--------	.00	.00	--------
	experiment	2	1.08	1.08	1.08	--------	.00	.00	--------
Intestine (small)	control	2	1.15	1.15	1.15	1.15	.00	.00	.00
	experiment	2	1.15	1.36	1.47	2.00	.21	.32	.85
Do	control	2	1.08	--------	1.08	--------	--------	.00	--------
	experiment	2	1.08	--------	1.11	--------	--------	.03	--------
Rectum, "large intestine"	control	2	1.09	--------	1.09	--------	--------	.00	--------
	experiment	2	1.09	--------	1.09	--------	--------	.00	--------

Table 14 shows the results of tests for invertase in extracts of mucosa throughout the digestive tract of the pickerel, showing the presence of invertase only in the intestine and here in very small amount.

A few tests were made for the presence of maltase and lactase. Maltase was found in great abundance in the hepatopancreas but not at all in the small intestine of the carp. It was present in small amounts in the small intestine of the snapping turtle. Tests for lactase in the intestine of the carp, Necturus, and the snapping turtle all yielded negative results.

GENERAL DISCUSSION

The relationship of nutritive processes to all the physiological activities of organisms makes the importance of obtaining a knowledge of the digestive enzymes in all groups of animals apparent. Extensive comparative studies of digestive enzymes in representative animals throughout the animal series would be of great value. In his comprehensive review of the work done in the physiology of digestion, Biedermann (1911, p. 1049) made the following statement in regard to the lack of knowledge of digestive processes even in the vertebrates:

> Wenn man von den karnivoren und omnivoren Säugetieren absieht, unsere Kentnisse der Ernährungsphysiologie hier kaum minder dürftig und lückenhaft sind als bei den Wirbellosen.

The data obtained show that apparently little change in the general character of enzymes or their rate of activity has occurred in the evolution of amphibians, reptiles, and mammals from primitive types. The rate of peptic digestion of coagulated egg albumin per given weight of moist stomach mucosa is remarkably uniform for the representatives of all classes of vertebrates studied. This substrate is equally well digested by the enzymes of fishes, amphibians, reptiles, and mammals. The reaction of the stomach in each group of poikilothermal vertebrates is variable, usually being acid when the stomach contains food and nearly neutral when the stomach is empty.

A close correlation exists between alimentary structure and the distribution of digestive enzymes. The data for the carp (which is a fish without a stomach or gastric glands) indicate that no pepsin is secreted by any part of the alimentary tract, and that the initial cleavage of proteins in this animal is largely by the trypsin from the hepatopancreas. Production of pepsin seems to be limited almost universally to a stomach mucosa possessing gastric glands. In a few cases, as in the frog, pepsin production has been demonstrated in the esophagus. In this animal, however, there is no sharp line of demarcation between the esophagus and the stomach. Extracts of esophageal mucosa from the pickerel, bull snake, and snapping turtle were tested for pepsin and none was found. While there was indication of a trace of pepsin in the intestinal mucosa of the pickerel and the turtle, it was not found in the intestine of other animals studied, and in all cases the presence of trypsin in any considerable quantity was limited to the pancreas (hepatopancreas in the carp).

The general occurrence of erepsin in the mucosa of the intestine in poikilothermal vertebrates is shown for the first time. This enzyme is present in as great or greater abundance in the intestinal mucosa of fishes, amphibians, and reptiles as in the intestinal mucosa of the dog.

Digestion experiments were carried on mainly at room temperature. For pepsin, trypsin, and erepsin parallel tests for representatives of each group of the poikilothermal animals and the dog were made at 37° C. With one exception (viz, peptic digestion in the pickerel, which will be further investigated) digestion was more rapid at 37° C. than at room temperature.

Certain adaptive features are shown in the relation of digestive enzymes to food habits. Those animals which include much plant food in their diet show a striking difference in the amount of carbohydrate-splitting enzymes from those that are wholly carnivorous. In the former amylase and invertase are present in much greater abundance than in strictly carnivorous animals. For example, the carp possesses a massive hepatopancreas containing large quantities of amylase, while extracts obtainable from the small diffused pancreas of the pickerel digest starch very slowly. Furthermore, the mucosa throughout the entire alimentary tract in the carp possesses amylase in considerably greater amount than is found in the mucosa of the alimentary tract in the pickerel. The bull snake, which is entirely carnivorous, possesses no invertase and little amylase as compared with that present in the painted and snapping turtles, which often include vegetable food in their diets.

CONCLUSIONS

1. The reaction of the stomach in each group of poikilothermal vertebrates studied is variable, usually being acid when the stomach contains food and nearly neutral when the stomach is empty.
2. No trace of pepsin was found in extracts of esophagus mucosa of pickerel, bull snake, and snapping turtle.
3. The rate of peptic digestion of coagulated egg albumin per given weight of moist stomach mucosa is remarkably uniform for the representatives of all classes of vertebrates studied.
4. With one possible exception, which the writer hopes to investigate further, peptic digestion in all classes of vertebrates was more rapid at 37° C. than at room temperature. Tryptic and ereptic digestion were always more rapid at 37° C. than at room temperature.
5. Erepsin is present in as great abundance in the intestinal mucosa of fishes, amphibians, and reptiles as in the intestinal mucosa of the dog.
6. Coagulated egg albumin is apparently digested equally well by the enzymes of fishes, amphibians, reptiles, and mammals.
7. Amylase is generally present in very small quantity in extracts of mucosa from the entire alimentary tract of fishes, amphibians, and reptiles. It is present in great abundance in extracts from the hepatopancreas of the carp and from the pancreas of Necturus, painted turtle, and snapping turtle.
8. Invertase occurs in the intestinal mucosa of the carp, blue gill, painted turtle, and snapping turtle, and to a slight extent in the pickerel. There was no evidence of invertase in the intestine of the bull snake and Necturus. Lactase was not found in extracts of the intestine of the carp, Necturus, or snapping turtle, the only animals in which lactase was sought.

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⁂

GROWTH AND AGE AT MATURITY OF THE PACIFIC RAZOR CLAM, SILIQUA PATULA (DIXON)

⁂

By F. W. WEYMOUTH, H. C. McMILLIN, and H. B. HOLMES

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INTRODUCTION

In the spring of 1923 the senior author was engaged by the Bureau of Fisheries to undertake the investigation of the razor-clam fishery of Alaska. The following summer, accompanied by Mr. Holmes, he spent 8 weeks in the field, visiting the Cordova beds and those near Chisik Island, Cook Inlet. In March, 1924, Mr. McMillin, who had been working on a similar problem for the State of Washington, entered the service of the bureau, and during the following summer accompanied the senior author for 10 weeks in the field, examining the beds at Cordova and those in the vicinity of Kukak Bay; the Washington beds were visited on the return trip.

The data collected was worked up at Stanford University by Mr. Holmes in the fall of 1923 and by Mr. McMillin during the fall and winter of 1924–25, under the supervision of the senior author. All general conclusions are the results of discussion and agreement of the three authors.

The study of growth and maturity forms the main part of this paper. These matters are not only of scientific interest but are of importance on account of the bearing which they have on the measures of conservation that have been put into effect or may be recommended for the future. On this account the paper will be of more than usual interest to the men engaged in the clam industry of Alaska, and it has seemed desirable to include a discussion of certain matters which would not ordinarily be included in a strictly scientific paper, but which experience has shown will be of interest to the nonscientific reader and will lead him to a better understanding of the more technical portions.

We wish to acknowledge the advice and helpful criticism of Dr. Willis H. Rich during the progress of the work.

THE RAZOR CLAM

The razor clam, *Siliqua patula* (Dixon), occurs in commercial quantities from near the mouth of the Columbia River to the Aleutian Islands. Canning has been carried on at Warrenton, Oreg., along the whole coast of Washington, on Vancouver and Graham Islands in Canada, and at Cordova, in Cook Inlet, and Shelikof Straits, Alaska. This range possibly may be extended by the opening of canneries in southwestern Alaska along the Alaska Peninsula. It is essential to determine whether the variations encountered in this 2,800 miles of coast are of specific value.

The razor clam (*Siliqua patula*) was first described by Dixon in 1788 from specimens found near Coal Harbor, Cook Inlet, Alaska. Conrad found shells near the mouth of the Columbia River in 1838, and described them as a separate species—*Siliqua* (*Solen*) *nuttallii*. Later this was changed in rank to a variety of the original *Siliqua patula*. Other species and varieties exist, which, however, need not be considered here. A description of the two mentioned above, taken from Dall (1899, p. 109), is as follows:

> 3. *Siliqua patula* Dixon, 1788, Okhotsk Sea; the southern border of Bering Sea, and the Gulf of Alaska to Sitka.
>
> Described from Cook Inlet, Alaska. * * * Large, with the submedian beaks and straight rib. The following are discriminable varieties, but apparently connected by gradations with the typical *S. patula*.
>
> 4. *Siliqua* (*patula* var.) *alta* Broderip and Sowerby, 1829; Bering Sea and Strait. * * *.
>
> 5. *Siliqua* (*patula* var.) *nuttallii* Conrad, 1838, Lituya Bay, Alaska, south to Oregon, and California as far as Monterey.
>
> * * *. The shell is very straight, brilliantly polished, narrower than the typical *S. patula* and with a much more oblique rib. * * * .

A full copy of the original description is given by Oldroyd (1924, p. 58) without comment. The distinction given rests on the direction of the rib, which is said to be " straight " in " *patula* " and " more oblique " in " var. *nuttallii*," and on the proportional width of the shell, which is alleged to be broader in " *patula* " than in " var. *nuttallii*."

It is not difficult to separate Alaskan and Washington shells by their general appearance, but these differences are, we think, not of specific rank. The clams from the northern waters grow more slowly; the annual rings of growth on the shell, plainly visible upon even superficial examination, are thus more numerous and closely placed. While the number and placing of the rings may distinguish shells from various localities, these, as we shall show, are the result of environment and not specific differences. It is also found that clams on different sections of one beach grow at different rates. Specimens from places only a few feet apart but separated by some obstruction, such as the Grays Harbor jetty, may show decidedly different shell markings, and the growth curve constructed from shell measurements reflects the distinction.

The weight of shells from different beds also varies according to the rate of growth. As shown in Figure 13, the number of years necessary for clams to reach a certain size varies with the beds. Each year a new layer is added to the inner surface of the shell. In clams that have not reached their full size a thickened portion of the new layer extends beyond the margin, thereby increasing the size. The additions on some old clams increase only the thickness of the shell. Thus there is a relationship between the age of the shell and its thickness, and in comparisons both age and size must be considered.

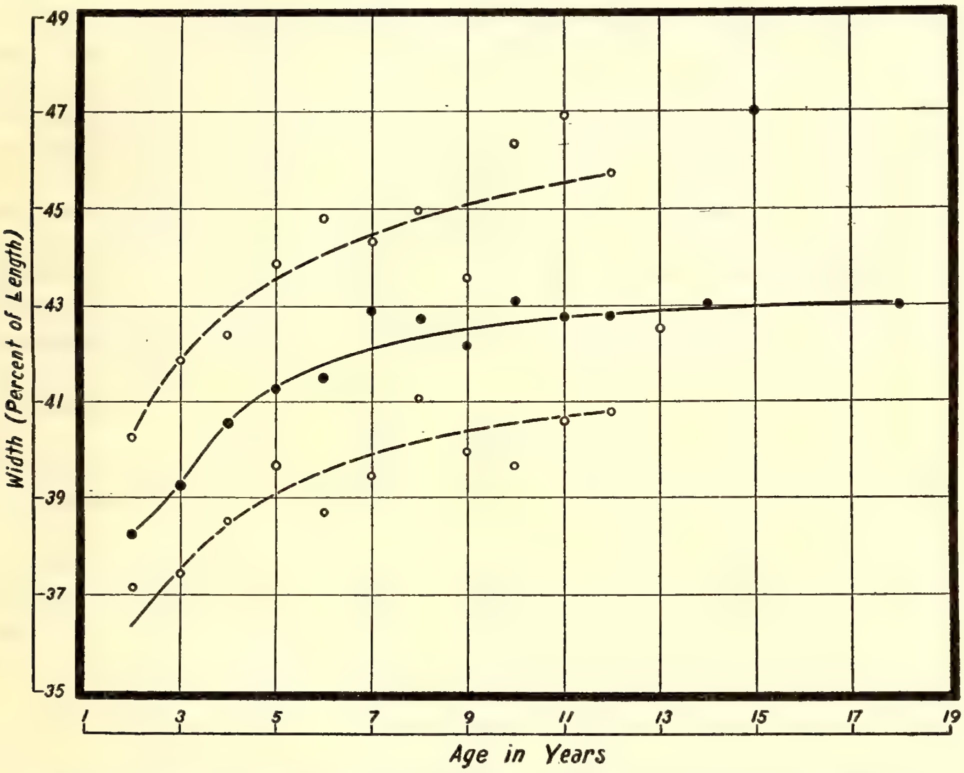

FIG. 1.—Showing increase in relative width with age. The solid line shows the median width at each age and the broken lines the 10th and 90th percentiles, between which are included 80 per cent of the widths. (Compilation of data derived from all sources.)

The direction of the rib is another point of alleged difference between the two varieties. It is charactized as "straight" in "*patula*" and "oblique" in "var. *nuttallii*." The rib is somewhat more oblique in young shells than in old ones, and as Alaskan shells, on the whole, are older than those from the Columbia River district, it seems probable that " var. *nuttallii* ", was described from younger shells than were used by Dixon for the original description. The direction of the rib varies between shells, but so far as can be determined there is no variation that is peculiar to or confined to one bed.

In the growth of the clam both length and width increase, but not in constant ratio. There is a variation between individuals of the same age and an increase in average width with age. The average relation of length to width (in percentages) at each age is plotted in Figure 1. The variation at each age is apparent; for example, at 3 years of age the width of eight out of every ten shells lay between 37.5 and 42 per cent of the length. If sufficient records are used to give a reliable average, it is seen that with increasing age the average width rises from about 38 to 43 per cent of the length. This change of relative width appears to be more closely correlated with age than with size. In comparing specimens of the same age from various localities we have been unable to find constant differences of significant size as compared with individual variation.

From what has been said it is clear that, in the description quoted above, the influences of age and relative size have not been considered, and that clams from the ranges of these two varieties do not differ significantly in the characters of direction of rib or of width of shell nor, so far as can be determined, in other features apart from those directly dependent upon environment. It will be noticed that " var. *alta* " is not included in this discussion. It is unsuited to canning and therefore is not considered in this paper. A thorough study of the shell and the soft parts shows it to be a separate species, distinct from *S. patula.*

The writers feel, after visiting beds on all parts of the coast and examining many thousands of shells, that the above views are sound. Excluding valid species, such as " var. *alta* " and *S. lucida*, which do not form a part of the commercial catch, we are dealing with a single form. Therefore, comparisons of its reaction to features of environment on different parts of the coast are valid. A more detailed consideration of these and other points of biological interest will be given in a later paper.

ANATOMY

Everyone who handles clams has noticed some of the more conspicuous parts and, since the mollusk is so different in structure from ourselves and other mammals, has wondered what the various organs are and how they work. The following brief sketch is intended to answer some of the most common of these questions and to give a glimpse of the plan of organization of a type of animal strange to most of us. A number of features of the anatomy of the razor clam merit more attention than is given here and may be treated later.

The clam, like other members of one group of mollusks, is protected by two similar shells or *valves* (hence the term *bivalves*), which are formed on the right and left sides of the animal, the back or dorsal side being that where the valves are joined together. This shell, which is so striking a feature of these animals, is a product of the *mantle*, a soft structure also characteristic of this group.

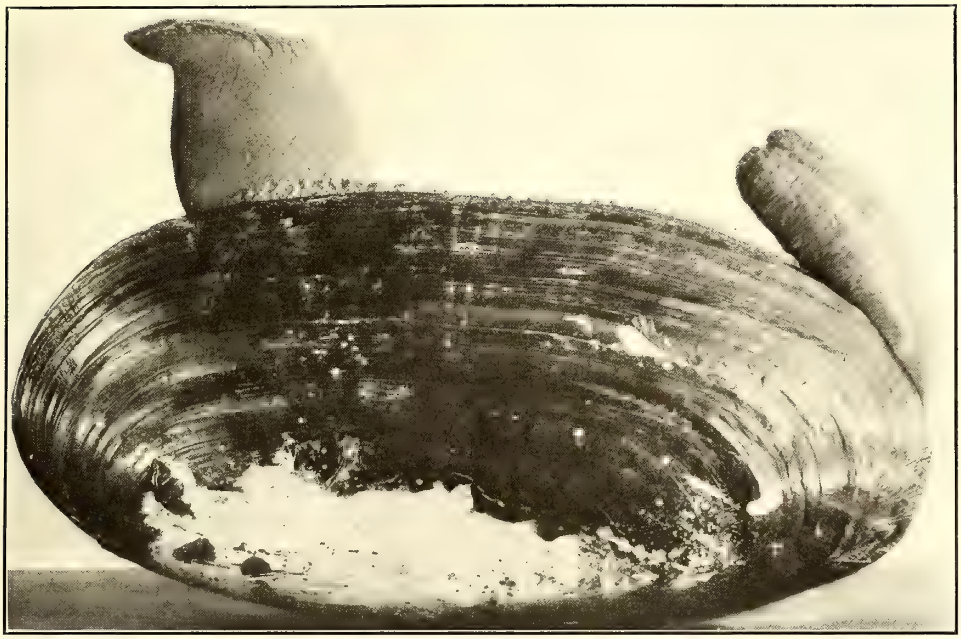

FIG. 2.—Razor clam, *Siliqua patula* (Dixon), side view

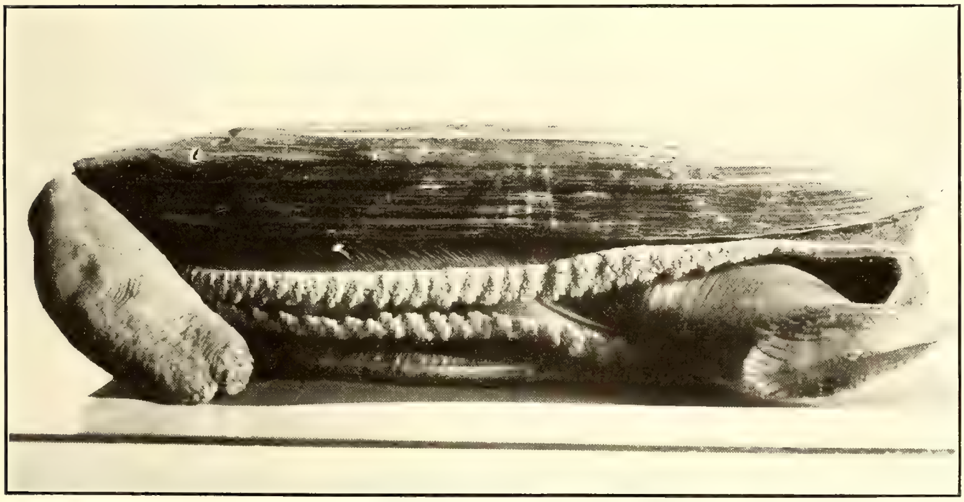

FIG. 3.—Razor clam, *Siliqua patula* (Dixon), ventral view

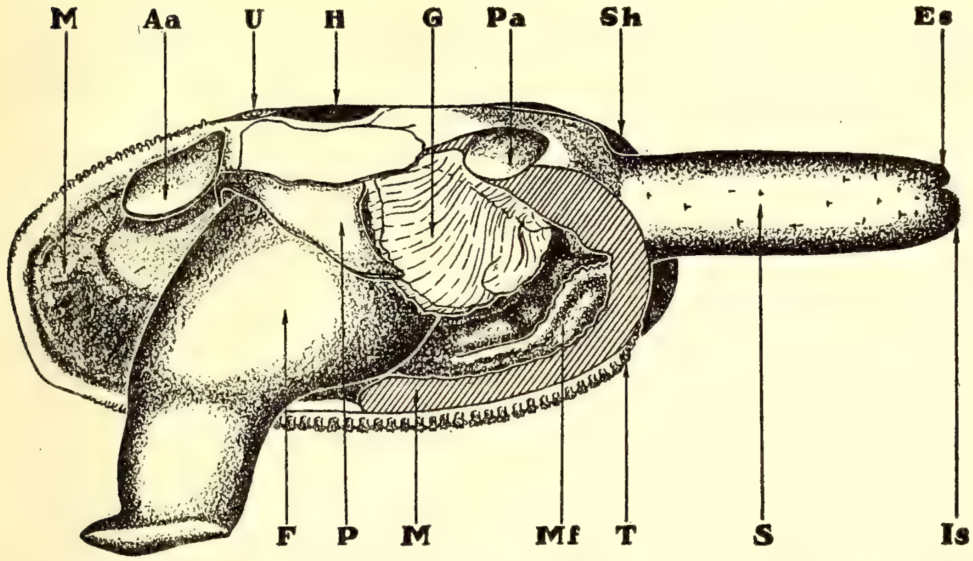

FIG. 4.—Razor clam. View of left side, with shell and mantle removed. *Aa*, anterior adductor. *Es*, exhalent siphon. *F*, foot. *Is*, inhalent siphon. *G*, gill. *H*, hinge. *M*, mantle. *Mf*, mantle fold. *P*, palp. *Pa*, posterior adductor. *S*, siphon. *Sh*, shell. *T*, papillæ. *U*, umbo

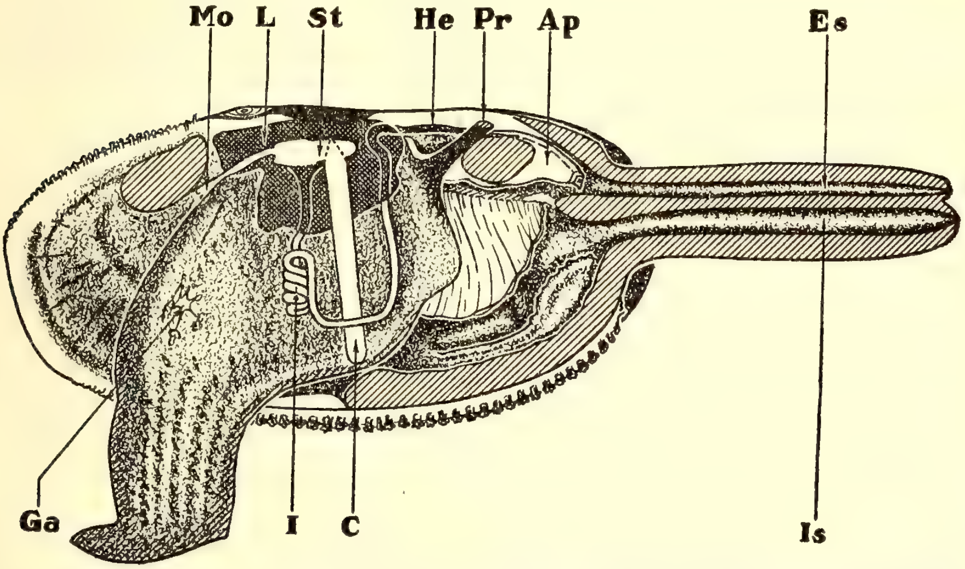

FIG. 5.—Same as Figure 4, but with left gills and palps removed, and siphon, foot, and visceral mass also removed. *Ap*, anal papilla. *C*, crystalline style. *Es*, exhalent siphon. *Ga*, pedal ganglion. *He*, heart. *I*, intestine. *Is*, inhalent siphon. *L*, liver. *Mo*, mouth. *Pr*, posterior rectractor. *St*, stomach

The *mantle* covers the animal as the flyleaves cover the body of a book, and by its activity secretes the valves of the shells, which thus come to occupy the position of the covers of the book. If we think of a book with limp leather covers, which bend over to meet each other around the edges and imagine the flyleaves doing the same thing, the picture is a very complete one.

Shells found on the beach or in the cannery shell piles lie flat, as an open book on a table. They are held in this position by the black hinge at the back. In life the valves are closed, to protect the animal, by the contraction of two large muscles, one toward each end of the shell. The muscles are called the *anterior* and *posterior adductors*, the latter being that nearer the siphon.

In the simplest form of mantle the edges are free except on the back, where the hinge is located, corresponding to the arrangement in a book, and the sea water may enter the cavity inclosed by the mantle at almost any place; this is the condition, for instance, in the oyster. In the razor clam, however, the edges of the mantle are fused, not only along the back, where the valves are joined together, but for about one-half of the remainder, chiefly at the posterior end. Three openings are left. The largest of these extends from the back around the anterior end and about halfway along the lower margin. Through this large slit the foot can be extended, and the hole is guarded by finely branched papillæ extending like ruffles along the margin (see figs. 4 and 5). When these are brought together, the sand is prevented from entering. At the posterior end the mantle is developed into a long double tube surrounding the two other openings of the mantle cavity. These form the siphon or "neck", which, contrary to the implication of the common name, is not at the anterior or head end but at the posterior or hinder end. We thus have, when the clam is feeding quietly in the sand, a fairly large cavity, in which hangs the main body of the clam, closed except for the double tube reaching up through the sand to the water above.

The mantle is lined with cells, most of which are covered with cilia—fine, microscopic, hairlike projections, but, unlike hair, always in vigorous motion. They lash sharply in one direction and return slowly, thus driving along any water that touches the mantle, like a myriad of tiny oars. The cilia on the mantle and gills all beat according to a plan which causes a current to flow out of the tube nearer the back, which is thus called the *exhalent siphon*, and in at the other, or *inhalent siphon.*

The water that passes through the mantle cavity supplies the clam with food and oxygen. The food consists of a great many microscopic plants and animals that live in the sea water. They are passed by the cilia across the gills (commonly called " livers " by those engaged in the industry) and the palps to the mouth, which lies just above and anterior to the foot near the anterior adductor. As the water passes through the gills it comes in close contact with the blood. An interchange takes place, similar to that in our own lungs in which oxygen is taken up by the blood and carbon dioxide given off. The waste products from the intestine are carried out by the water as it leaves the body through the exhalent siphon.

DIGESTIVE SYSTEM

The mouth of the razor clam has the shape of a flattened funnel and leads directly into a slender œsophagus. The œsophagus opens into the stomach, which lies directly under the hinge and in this clam is comparatively large; it is surrounded by a dark "liver," which secretes digestive juices into it through wide open ducts. The posterior part of the stomach is lined with cartilaginous tissue, from the bottom of which a long diverticulum extends downward to the lower margin of the foot. This is filled with a clear, gelatinous rod called the "crystalline style," containing a starch-digesting enzyme similar to that of the saliva.

The intestine leads downward from the middle of the stomach and is coiled below the liver, from whence it follows the posterior margin of the foot upward through the end of the liver. Here it turns abruptly backward, passes through the heart, over the posterior adductor, and ends in a fleshy papilla at the base of the exhalent siphon. There are two dark-colored kidneys, one on either side near the heart cavity.

NERVOUS SYSTEM

The nervous system of the razor clam is very simple, consisting of three pairs of ganglia. The *cerebral ganglia* lie on either side of the mouth near the lower surface of the anterior adductor muscle. The *visceral ganglia* occupy a somewhat similar position on the posterior adductor muscle; they are more closely united than are the cerebral. The *pedal ganglia* are closely fused and are embedded in the muscles of the foot. These pairs of ganglia are connected by nerves. There are no special sense organs except a pair of minute statocysts, or balancing organs, lying on either side of the pedal ganglia.

LOCOMOTION

One of the most interesting things about the razor clam is its unusual ability to move through the sand. The foot is quite different in shape from that found in the soft-shell and butter clams, being elongated and nearly cylindrical instead of flattened. It is a very effective burrowing organ, and, unlike many others, the razor clam retains throughout life a high power of active movement. In burrowing, the foot is extended from the shell; the tip, which is pointed, is thrust through the sand, and, when fully extended, the tip expands, forming an effective anchor. The foot is then retracted, drawing the body toward this anchored portion. Repetition of this action gives the clam a rapid movement.

The mechanism for the retraction of the foot is easily demonstrated. The bulk of the elongated foot consists of longitudinal fibers. These are connected with the shell by two specialized retractor muscles (anterior and posterior), one of which lies near each of the large adductor muscles which close the shell. The combined contraction of these shortens the foot with considerable force.

The method by which the foot is extended is less well understood. Clams taken out of the sand very often discharge a large amount of fluid from the tip of the foot, apparently through a rupture of the body wall. It is generally assumed that the contraction of the circular fibers of the foot and visceral mass forces this fluid to extend the foot by hydraulic pressure.

SPAWNING

In most mollusks the sexes are separate; in a few, however, both eggs and sperm are produced by the same individual. In the razor clam, as in most forms, all observations have shown each individual to have germ cells of one kind only. The reproductive material is cast into the water at spawning time, and there fertilization and further development take place.

Only by examination of the gonads is it possible to tell the sex of the clam. There are no superficial characters that betray the sex. If the contents of the gonads are spread on a glass slide or on a scalpel, a marked difference between sexes is apparent. The ova have a granular appearance, in contrast to the viscous homogeneous mass in which the sperm is found. The sexes of the entirely immature clams can be determined only by microscopic examination of tissue, which was not carried out in this case while in the field. A large number of clams in more advanced stages of maturity were examined and the sex recorded. This was done for two reasons—to determine the stage of maturity and to make sure that both sexes were equally represented. As far as has been determined both sexes pass through similar stages in an equal period of time, and from the standpoint of maturity and growth they do not differ, hence, in the following calculations the sexes have been combined.

TIME OF SPAWNING

Data were obtained from the 1923 and 1924 spawning seasons on the Washington coast (McMillin, 1923). These two spawnings differed somewhat and may represent two extremes. As described in the above reference, the 1923 spawning took place on May 30, 31, and June 1. It was practically simultaneous, and the major portion was completed in a very short time. As a result of this spawning a heavy set of young was produced, the average per square foot on the whole beach numbering more than 1,400. The spawning of 1924 was different, apparently because the temperature during May was variable and the average remained low. Spawning started on a rise of temperature on June 12, the rate of discharge of eggs was reduced by lowered temperature on June 14, and after that spawning continued slowly for two weeks. Although the action was slow, all observations showed the clams to be acting in unison, and at any one time all seemed to be in the same condition. The result of this year's spawning was negligible, no specimens representing this class having since been found.

In 1923 the spawning on the Oregon coast was not followed. On the North Beach section of Washington, extending from Willapa Harbor to the Columbia River, spawning started on May 19. On the section beween Willapa and Grays Harbors it started on May 24, and on the Copalis section, as already described, on May 30. In each of these sectors the whole population of the beach spawned at the same time. No data were collected for the Queets and Kalalock beds of

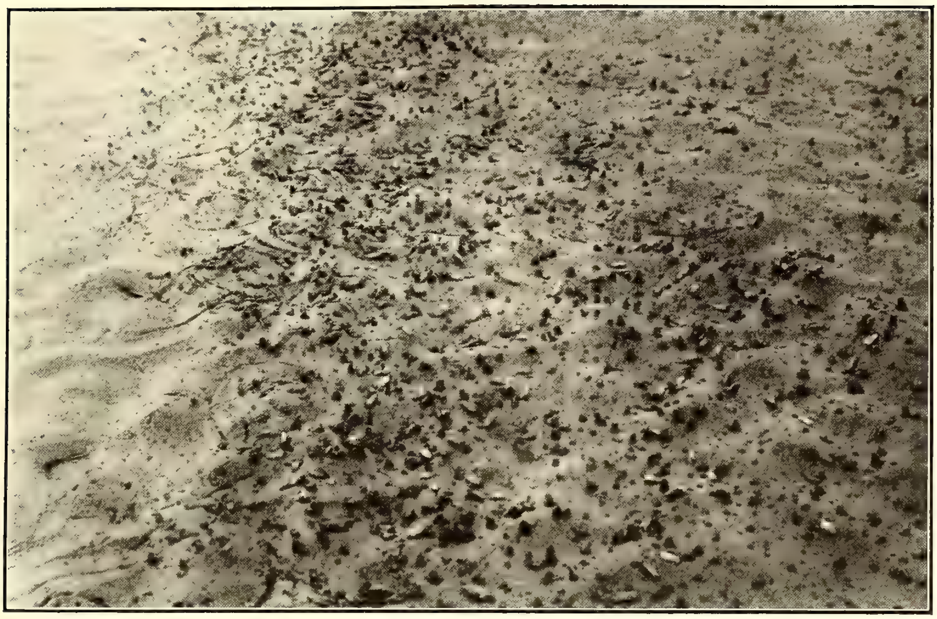

FIG. 6.—Small clams, Copalis beach

FIG. 7.—Digging on the "river spit," Swickshak beach

northwestern Washington. There is no available information on spawning on the Vancouver Island and Graham Island beds in Canada.

While visiting the canneries and beaches of Alaska, as many observations as possible were made on the condition of the clams at various times. During the season several cannery men preserved specimens in formalin at stated intervals. These specimens were collected and examined further to determine the amount of reproductive material in the gonads during each part of the season. In this way it is possible to fix approximately the spawning season for each section from which specimens were obtained.

Spawning records for the vicinity of Cordova are very incomplete. The observations made on preserved material and the examination of clams on the beds indicate that spawning started soon after July 1, 1924. On July 13 but 2 per cent of the clams showed they had recently spawned out, 10 per cent had full gonads of such consistency as to indicate no active spawning, and the remainder (88 per cent) showed various degrees of incomplete spawning. On August 15, when over 400 specimens were examined, but 2 per cent carried any appreciable amount of spawn, 28 per cent showed the presence of a small amount of reproductive material, and 70 per cent were completely spawned out.

The two records cited above were taken over a month apart. They give a fair example of what is found to exist generally in Alaska. There is no short common spawning season, as is found on the Washington beaches, but rather a gradual changing over in the condition of the clams, from those in midsummer with large, full gonads to the thin, spent ones in early fall. The process takes over a month, although it is probable that any particular individual may cast its entire spawn more quickly.

Similar conditions are found to exist elsewhere in Alaska. Near Chisik Island in Cook Inlet observations were made during the summer of 1923. The clams appeared fullest, or " fat," in late July. Evidently spawning started between July 25 and 30. After August 1 it proceeded more rapidly and continued as long as specimens were obtained. On September 25 a few showed the presence of a very small amount of reproductive material, but it is doubtful if any spawn was being cast.

The figures from Swickshak Beach for 1923 and 1924 show that the clams develop reproductive material rapidly in early May. By July 1 they are quite full, and they start spawning between July 20 and 25, but proceed most rapidly after August 1. They appear to spawn out somewhat more rapidly than on either the Cook Inlet or Cordova beaches. Before September 1 spawning was completed.

RELATION OF WATER TEMPERATURE TO SPAWNING

From the excellent work of Dr. Thurlow C. Nelson (1921) it is apparent that the water temperature is closely correlated to the spawning of the oyster. A critical temperature of 21° C. (70° F.) has been found, below which oysters will not spawn. Above 21° C. spawning will take place more rapidly as the temperature increases. It is further stated that due to continued cold weather, where the water has failed to reach the critical temperature for any length of time, the eggs will not be cast, but rather be resorbed by the oyster.

From the meager data available it appears that temperature influences the spawning of the razor clam very much as it does the oyster. During the winter the gonads are very small; they consist of a series of tubules lying among the muscle bundles of the foot and about the intestine. After the first rise in temperature in the spring the gonads increase in size. They gradually distend the visceral mass until they form about 30 per cent of the total body weight and cause a decided gape in the shell. The eggs and sperm are contained in follicles within the tubules. Shortly before spawning it appears that the follicle walls are ruptured or disappear, and the reproductive products are then free within the tubules.

While more data would be desirable, available records indicate that the temperature of the water over the beds is closely related to the act of spawning. It is known that a high temperature is accompanied by rapid spawning of the clam, and a drop in temperature arrests progress. During the season of 1923 the temperature of the water over the beds at Copalis rose steadily from 8° C. on March 27 to 11.5° C. on May 20. During this time there has been a constant increase in the size of the gonads but no active spawning. Between the taking of the temperature at 6 a. m. on May 29 and a similar time the following day there was a rise in temperature from 11.4 to 13.1° C. (See fig. 8.) Spawning started quickly and with great vigor. There was no appreciable drop in temperature, and spawning was nearly complete in two days. Some eggs remained in the gonads, but they were few in number compared with the great mass that had been cast.

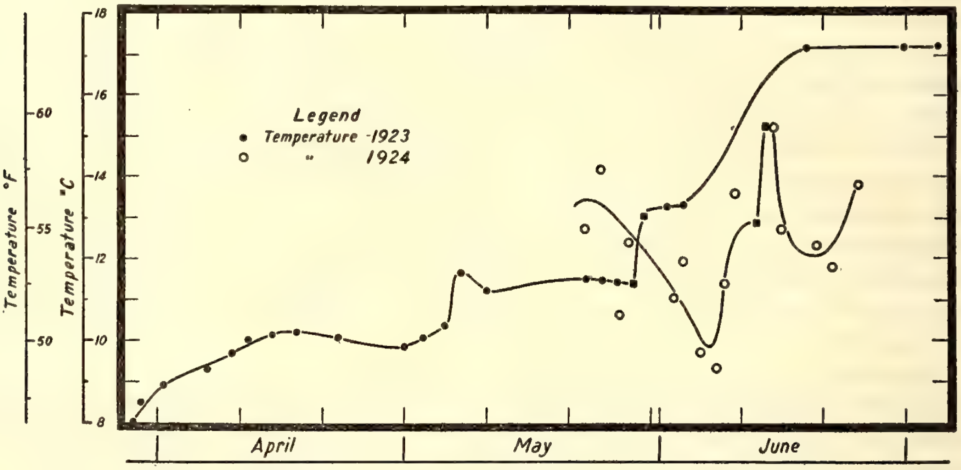

FIG. 8.—Showing water temperatures at Copalis during the seasons of 1923 and 1924. The rise of temperature that immediately preceded spawning in both cases is indicated between the square dots (■—■)

The following year (1924) spawning started 14 days later. The temperature of the inshore water, as well as that at the Columbia River Lightship off the mouth of the Columbia River, was more variable than that of the previous year. Again spawning started immediately following a rise in temperature, which in this case was from 12.8 to 15.3° C. Two days later the temperature dropped sharply to 12.6° C., accompanied by a greatly reduced rate of spawning. Less spawn was cast in 10 days during this period of low temperature than during the 2 days of the preceding year. From all indications spawning may have been suspended entirely during part of the time. No attempt was made to correlate the rate of spawning with the number of larvæ in the water, which Nelson has shown to be possible with the oyster. The condition of the clams was determined by opening a large number and making direct observations on the contents of the gonads.

Temperatures taken in Alaska near the spawning time were very similar to those on the Washington beds. The open beach near Cordova had a temperature of 13.9° C. on July 16, which was shortly after the onset of spawning. The protected waters of Orca Inlet and adjoining bays from which claims were taken varied in temperature from 12.8 to 14.5° C. The temperature records from Swickshak Beach showed an average of 13.5° C. at spawning time.

These figures suggest a critical temperature of about 13° C. (55.5° F.) for the razor clam, as compared with 21.0° C. (70° F.) for the oyster. The summer temperature of the Alaskan waters is quite high in all cases, except where influenced by glaciers or glacier-fed rivers. The variation from day to day in the Ketchikan records is less striking than on the Washington coast. For instance, the variation at Ketchikan for the month of July was from 13.5 to 16.0° C., and for August, 13.0 to 17.0° C. In contrast to this, similar figures for the Washington coast were as follows: July, 10.6 to 17.2° C.; August, 11.1 to 17.2° C. On two occasions during the summer of 1923 the temperature of the shore water at Copalis dropped more than 6° (centigrade) over night. This cold water was accompanied by a fog which was largely confined to the beach. Crab fishermen outside the harbor declared it was clear a short distance offshore, and personal observation showed the fog to extend not more than half a mile inland.

A few hours after the cold water was noticeable on the beach a peculiar collection of material was cast up by the surf. It contained a great many sponges, snails and snail shells, worm tubes, cast crab shells of several varieties, and a great mass of other detritus, which ordinarily rest lightly on the bottom. This indicated the presence of a current of comparatively high velocity moving landward over the bottom, which caused an upwelling of cold water along the shore. It was evidently of small extent, as it affected not over 20 miles of coast line.

It was suggested by McEwen, in a personal communication, that this upwelling was not similar to one described by him (McEwen, 1912) from the California coast but, rather, it was caused by some local condition of the air currents. While the Ketchikan temperature record does not show the sharp transient drops that might be expected from such an upwelling, this would not prove that upwellings do not occur in this region. Their effect would be most marked on the outer coast; as, for example, on the west side of Prince of Wales Island the circulation of the tide among the many islands of the Alexander Archipelago would tend to obscure fluctuations of the inland waters about Ketchikan.

As has been shown by J. Nelson (1917), oysters acclimated by living for many years in the Gulf of St. Lawrence have a reduced critical temperature of 20° C. (68° F.). It has been further shown by T. C. Nelson (1921) that oysters moved from New England to New Jersey spawn two weeks earlier than do the native oysters. Those moved north from Virginia spawn later than the native strain.

The critical temperature for the razor clam of Alaska is probably not lower than for those on the Washington beach, as the slight difference in summer temperature probably insures an opportunity for spawning along the whole coast under similar conditions. The temperature of the inshore waters, from Pismo, Calif. (the southern limit of *Siliqua patula*), to the end of the Alaskan Peninsula, is quite uniform during the summer.

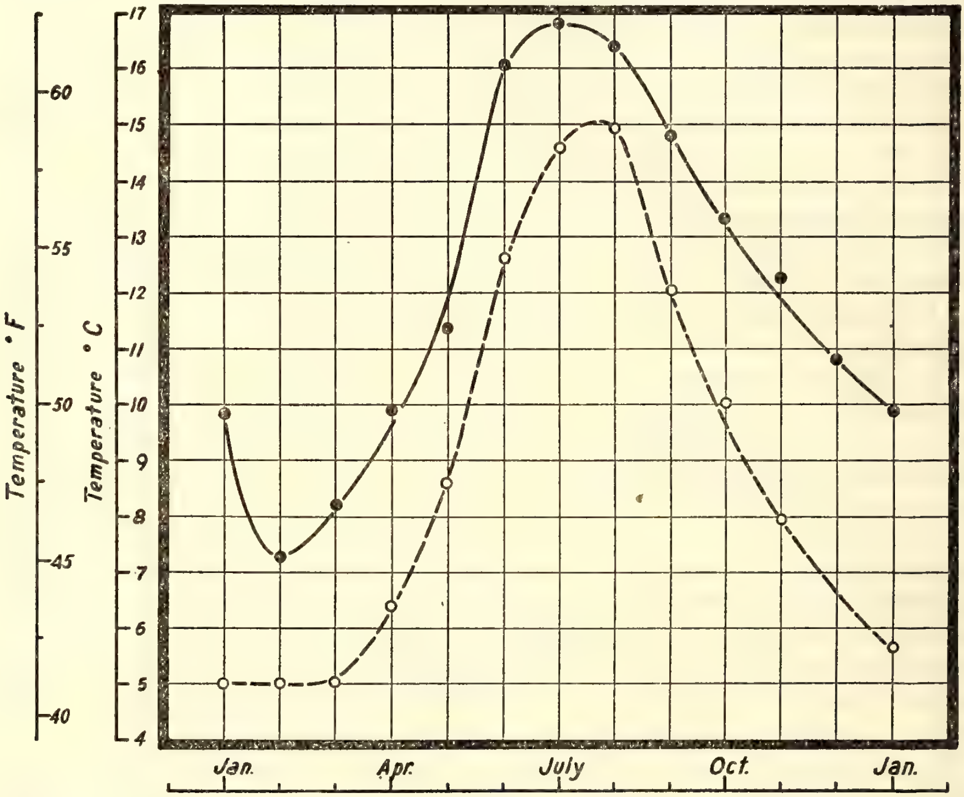

FIG. 9.—Showing the mean (average) monthly temperatures for Washington beach and Ketchikan (Ketchikan temperatures furnished by U. S. Coast and Geodetic Survey). ● — ●, Washington beach; ○ — ○ , Ketchikan

The temperature record for Ketchikan is the only complete set for Alaskan waters. Comparison of these with records taken over the clam beds indicate that they are representative of conditions that exist generally over the whole region. The more southern waters reach what might be called a normal temperature earlier than do those farther north, and they also cool later in the year. For instance, the Washington temperature was above 13° C. for twice as long as was the temperature at Ketchikan during the 1923 season. (See fig. 9.) The mean temperature for each month showed a difference in the maxima of 1.8° C., while the actual difference was illustrated by the reading on August 5, which was Washington, 17.2° C., and Ketchikan, 17° C.

LARVAL DEVELOPMENT AND GROWTH OF YOUNG

The spawning season of 1923 presented an excellent opportunity for the study of larvæ on the Washington coast. Spawning took place in a very short time, and the razor clam larva was the predominant form taken in plankton tows made during the time when they were swimming. Three weeks after spawning the larval stage appeared in the tows. At that age the shell is transparent and can be seen only when shattered by slight pressure. One month after spawning a great number of what proved to be half-grown larvæ were found in the surf at high tide. In tows taken in 4 feet of water at the same time many similar larvæ and some larger ones were found. More were taken at high tide than at low tide. This may have been due to the flood tide raising the larvæ out of the surface layer of the sand and carrying them in the surf during the remainder of the flood and part of the ebb of the tide. As the larvæ increased in size more were found in the sand, and at the same time the numbers in the tows decreased. All clams were considered as larvæ until they had opaque shells covered with a brown periostracum, and the shape had become markedly elliptical.

There is no evidence of extensive migration of adult clams. In fact, observations point to a very limited range for any individual. The distribution occurs mainly during the larval stages. As the period during which the young are in the swimming stage amounts to about eight weeks, the excellent set resulting from one spawning would indicate that the larvæ are largely confined to the sand. If the eggs and larvæ were free for this length of time they would probably be so widely scattered that the original beds would not be heavily stocked. The eggs sink quite rapidly and are not easily raised by surf action. They are probably discharged at the surface of the sand. If they sink as soon as they have left the body of the mother and resist the action of the surf, which would tend to scatter them, they would be fertilized in great numbers in the surface layer of the sand. As they also spend a large part of their larval life in the sand, it is not surprising that the resulting set in one place is enormous. However, the young clams do swim and the eggs are doubtless moved about, but apparently not to the extent that might be expected from an eight weeks' larval period.

LENGTH OF LARVAL LIFE AS COMPARED WITH OTHER MOLLUSKS

The length of the larval life of the razor clam seems quite long when compared with that of other mollusks. It has been found by Nelson (1921) that the eastern oyster (*Ostrea elongata*) has a free-swimming stage lasting from 14 to 18 days. This was determined by direct observation under known conditions of salinity and temperature.

According to Kellogg (1910) the soft clam (*Mya arenaria*) swims as a larva for from three to six days. The general observations from which this indeterminate period was inferred are not very satisfactory. A number of difficulties are encountered. Attempts to rear them artificially were unsatisfactory, and because of the extended breeding season and the numerous similar young of other mollusks the direct observations of the larvæ were not decisive.

Belding (1910 and 1912) concluded that the quahog (*Venus mercenaria*) remained a free-swimming larva from a week to 12 days, while the pecten (*Pecten irridans*) passed through the corresponding stage in about a week. It was concluded by Field (1922) that the common mussel (*Mytilus edulis*) remained in the free-swimming stage about two months when living under natural conditions. He compared the specimens taken in nature with those raised in an aquarium and arrived at quite definite conclusions.

This length of time agrees more closely with the larval period of the razor clam. The larvæ differ in one respect, however, as the mussel is actually swimming during the greater part, if not all, of the period, while the razor clam is more inclined to remain in one place. The mussels are scattered over a great area and are dispersed by this method. The habitat of the razor clam is more limited, and the larvæ do not scatter to a like degree.

TIME OF SETTING AND GROWTH OF YOUNG

Eight weeks after spawning large clam larvæ visible to the unaided eye were found in a quiet lagoon. None of this age was taken with the plankton net in the surf, although repeated attempts to do so were made at several places. It is probable that the majority had already passed through this stage. The larval shell was now dense enough to hinder observation of the organs, and the posterior end had a marked tendency toward the elongation which is so marked in the adult clam. Prominent gills were present, but no velum was seen.

While under observation the live specimens would extend the characteristic long foot from the shell. Five days later small clams in the adult stage were found in the surface of the sand. They averaged 0.25 centimeter in length and were the forerunners of a very heavy set. Distribution was slightly uneven, although they were everywhere abundant, averaging approximately 1,450 per square foot. At this size they were found in the surface layer of the sand, and if a small hole was dug in the wet sand it quickly filled with water in which there were a number of small clams. If the water in this depression were given a circular motion with the hand, a number of small clams, as well as sand from the edge, were dislodged. The clams tended to be whirled to the center, but as they are very active, even when being carried quite rapidly over the surface of the sand, they will catch their foot in the sand and disappear from sight.

At intervals large numbers of small clams were taken by screening the sand. These were measured and the median size determined. (See fig. 10.) During the month of August the small clams increased in average size from 0.25 to 0.88 centimeter. The following month they grew to 1.39 centimeters in average length. A marked decrease in the rate of growth was found in October, during which month an increase of only 0.24 centimeter was shown. At this time the average length was 1.63 centimeters, and no further growth was observed.

MORTALITY OF YOUNG

The preceding paragraphs give some idea of the great number of small clams that may settle in the sand in late summer as the result of a successful spawning year. The set is not equally heavy in consecutive years. Some years the young are very numerous, while at other times it is difficult to collect specimens enough for an examination. The abundant set of 1923 gave an excellent opportunity to study the mortality as well as the growth of these small clams during the first season.

On August 1 the young clams, now only 0.25 centimeter in average length (about ⅛ inch), were found on the beach in great numbers. From four counts the average number per square foot was found to be 1,451. In determining the distribution the clams were taken only from the top layer of the sand about 2 inches in thickness. The shifting of the sand may account for some errors, as Thompson (1919) has shown that the action of the surf on exposed sand beaches continually changes the topography of the beach. This was illustrated by the counts of September 1 and 9, in which 986 clams per square foot were found on the first date, while 1,122 were found on the same area nine days later.

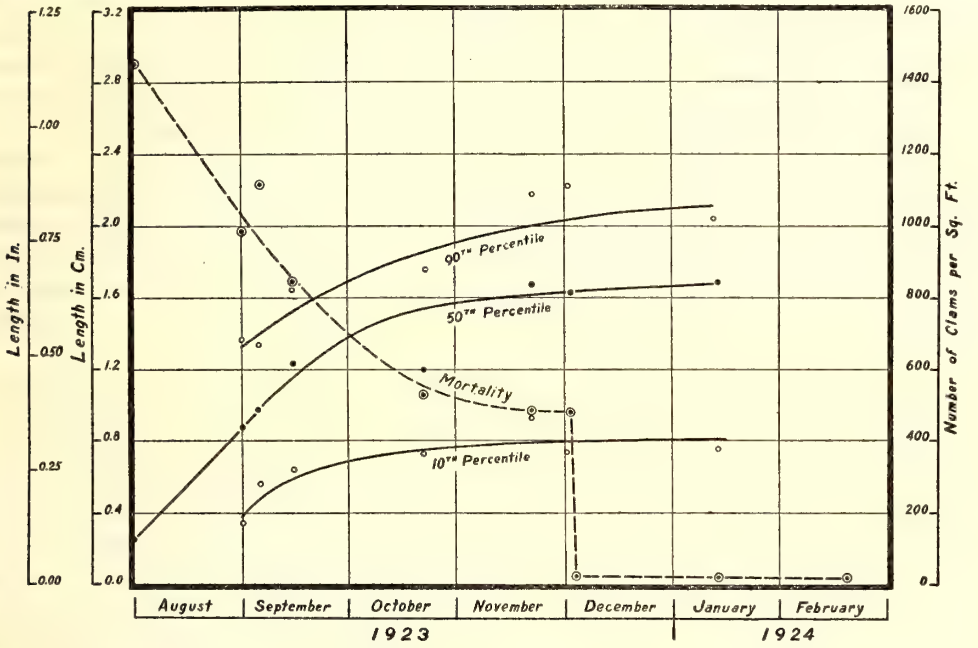

FIG. 10.—Showing the growth and mortality of small clams on the Copalis beach of Washington in 1923. Solid lines, read from scale on the left, indicate growth, showing rapid increase in size during August, soon after settling in the sand, and no increase during the winter. The broken line, referred to scale on the right, shows the decrease in numbers of small clams per square foot. The sudden drop in early December was due to a storm

As indicated by the figures just given, there was a steady decrease in the number of clams per unit area. By late fall they had been reduced to a third of the original number. On December 4 there was an average of 494 per square foot. On that date a heavy storm strikingly changed the topography of the beach. An extraordinarily heavy surf dragged the sand from the high beach out into deep water. Certain sections of the beach were lowered 4 or 5 feet. While it is natural to assume that a great number of the small clams perished, undoubtedly many were carried out into deep water where their survival is uncertain.

A census of the beach immediately after the storm showed very few clams. Some places were entirely barren, but an examination of the entire beach gave an average of 18 per square foot. During the winter there was a lighter mortality, leaving about 16 per square foot when examined the following February. Of these survivers very few, if any, were left the following summer. Thus we see that the number of small clams resulting from one spawning is no criterion of the extent to which that year class will affect the commercial catch. The records given above show the total loss of a very heavy set; therefore, a successful spawning does not necessarily indicate that the population of the beds will be increased by it.

The fate of clams removed to the area below low tide is questionable. Small clams are not found in water deeper than 12 feet, and probably only stragglers among the mature clams are found far from the intertidal zone. In the instance cited above a great many may have been removed to the area exposed at the lowest tides only or bordering these areas. They would then supplement the number already there, and might even spread out and return to the higher levels, where they might be taken by the diggers.

The State of California is attempting by a yearly census to find the abundance of the annual set and to follow the survival of the young of the Pismo clam from year to year. This is done by taking all clams from a trench crossing the entire beach. The process is repeated at several places in order to obtain a reliable average. The clams are then sorted as to age, and the number of each class for each meter of trench is recorded. The result of the last census is given by Herrington in a paper which will appear in an early number of the California Fish and Game Bulletin (1925). A similar system of annual surveys of the Washington beach, supplemented with the examination of the cannery shell piles, would give an index of the beach population. The census of the set each year, with an analysis of its subsequent effect upon the commercial catch, would make it possible to determine the result of fishing, protective measures, and to foretell with some degree of accuracy the amount of the commercial catch.

GROWTH OF THE ADULT

RING METHOD OF AGE DETERMINATION

The size at various ages is a matter of very great practical importance in various questions, such as the determination of age at sexual maturity and the efficiency of protective legislation. Since the absence of direct observation which can fix the age has made is necessary to use extensively the indirect determination by " annual rings," a short statement of this method will be desirable.

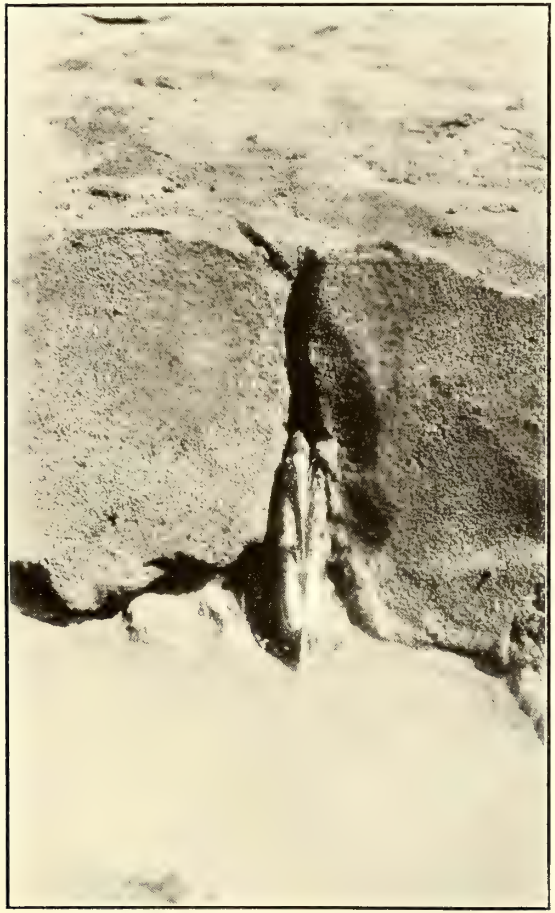

FIG. 11.—Clam in a burrow, ventral view

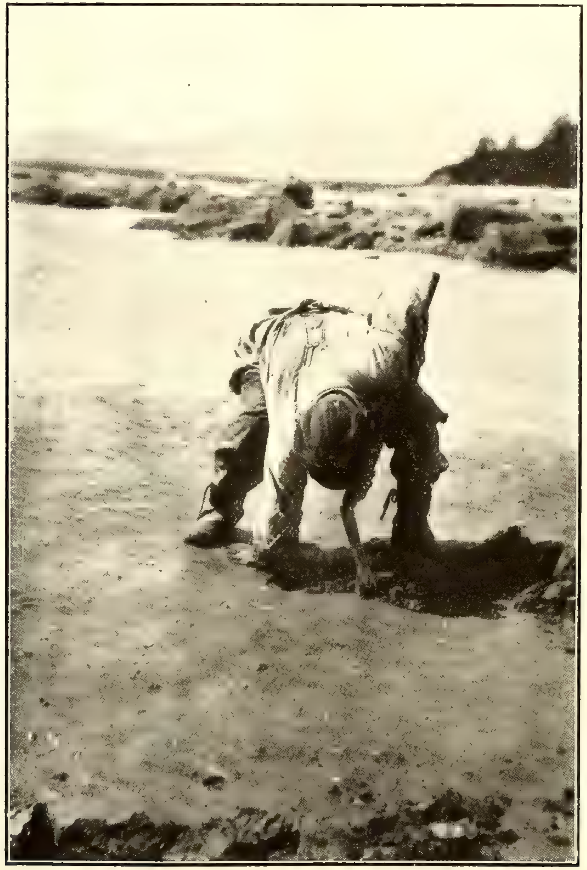

FIG. 12.—Native digger, Snug Harbor

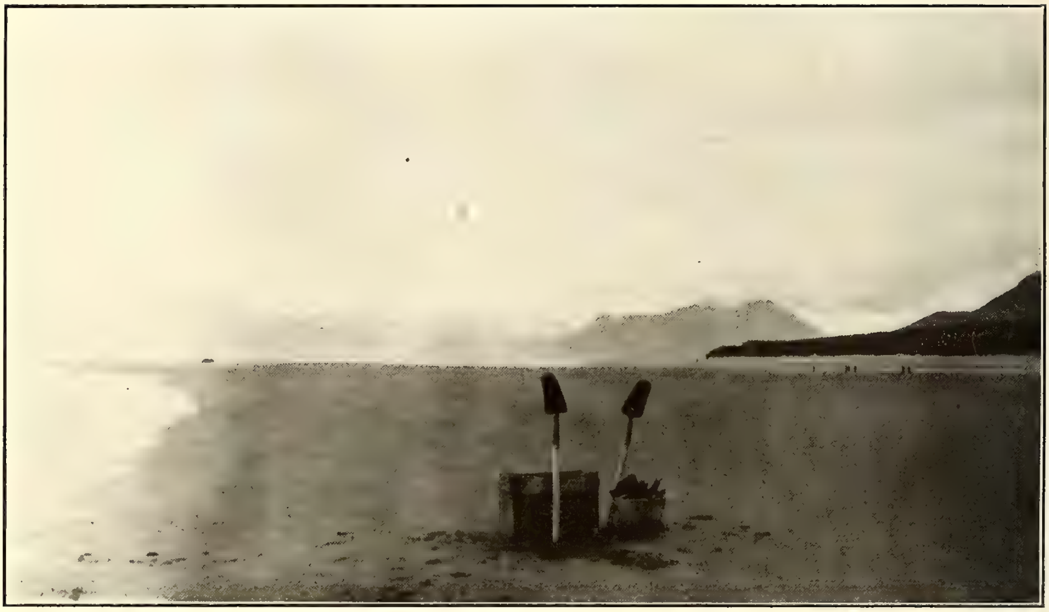

Fig. 13.—Clam digger's equipment, Swickshak beach

The method is that which has long been unquestioningly applied to trees, which, in their structure, show evidences of the number of seasons through which they have passed. The annual nature of the "rings" visible in the shell of the clam has been clearly proved by the senior author (Weymouth, 1923) in the case of the Pismo clam. The same method has already been applied to the razor clam (McMillin, 1923). In brief, it rests upon the fact that the clam does not grow at a uniform rate, growth being rapid in summer and slow or absent in winter. This is illustrated by the results obtained by following the young of the Pismo clam through two years (Weymouth, 1923) and the small razor clams through one year.

Figure 10 (reproduced from McMillin, 1923) shows the absence of growth during the winter. The possible reasons for this, chief among which appears to be temperature, are discussed in detail in the papers referred to and need not be considered further here. For our purpose it is sufficient to note that the rings are formed during the season of slow growth. This is confirmed by many observations on the razor clam, in that the relation of the rings to the growing margin of the shell in clams small enough to show appreciable annual growth is always what might be expected for a winter formation of the ring. They lie close to the margin in the spring, farther away in the summer, and farthest in the fall.

This is further supported by the study of size frequencies. During the winter all clams were taken from a certain area of beach and their total lengths recorded. By tabulating these in size classes a frequency table was obtained from which a curve was constructed (McMillin, 1923; fig. 8). This curve showed modes the location of which corresponded to the lengths of the annual rings for the second and third years. After the third year the overlapping in size of the different year classes obliterates the modes of each class.

The annual ring is a structural feature of the shell and not a superficial mark. In the broken shell a layer marking the surface of the shell at the time the ring was formed can be seen extending from the ring on the present surface through the entire shell. A white line remains on the underside of the periostracum when it is peeled off. This is found to mark the location of the annual ring. Some feature of the growth about the time of the formation of the ring causes the periostracum to become fused with the calcified portion of the shell, thus giving emphasis to its location. From these facts it is clear that a ring of definite character is formed once and only once each year and is therefore a definite indication of age.

The difficulties in applying this method are of three kinds. (1) Injury to the edge of the shell in summer may retard the growth and cause a check that might be confused with the annual ring. (2) A first and sometimes a second ring is difficult to determine on clams 12 or more years of age, as these early rings are formed on very thin shells and may be removed by erosion. (3) The crowding of the annual rings near the edge of the shell, due to the very small increment of growth, makes the location of the last rings in old shells indefinite. From the above causes some records may be in error, but the number and magnitude of these are not large, and because of the great number of observations the general results can not be appreciably affected.

GROWTH IN DIFFERENT LOCALITIES

Many shells of various localities have been examined and the total length of each ring determined, thus giving a great mass of records of lengths at known ages. All measurements were made with one caliper by one or two persons. The caliper was graduated in millimeters, and by the use of a vernier scale could be read to tenths of millimeters. While all measurements were made and recorded in tenths of millimeters, the last place was not used in calculations. A few measurements were made in the field, but the majority were made in the laboratory. There is usually a change in density or pigmentation of the shell at the annual ring. The use of light to make these zones more apparent was found to be very helpful. If a shell is exposed to direct sunlight or a strong arc or incandescent light is placed under it, the annual rings show up in such a way that they can be measured without difficulty.

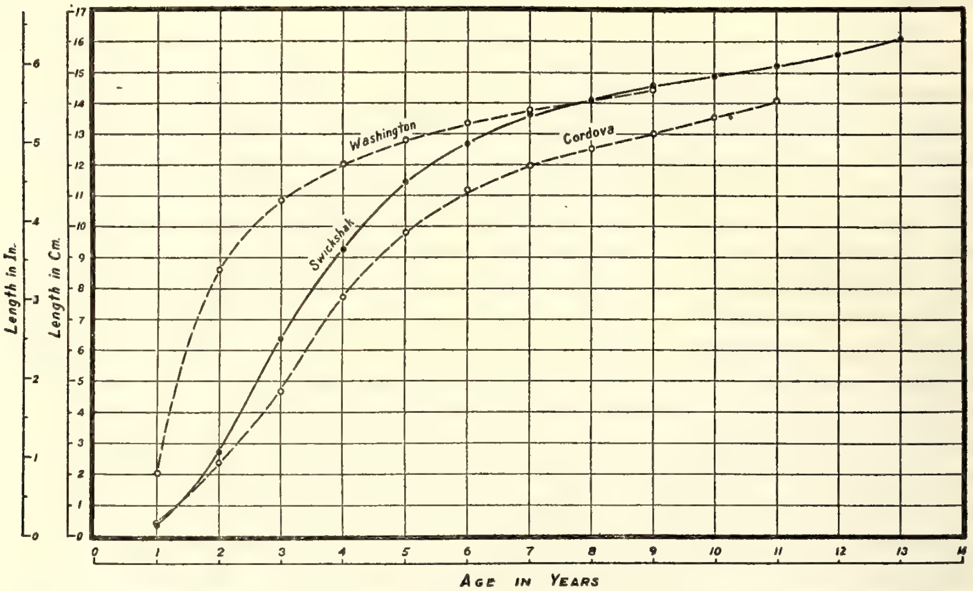

FIG. 14.—Showing the growth of clams from three localities. From this the average size for any age can be read. For example, the lengths for 3 years of age are as follows: Cordova, 4.61 centimeters (1¾ inches); Swickshak, 6.41 centimeters (2½ inches); and Washington, 10.87 centimeters (4¼ inches). The legend of the abscissa "age in years", is used for convenience. The age rings form first at ½ year of age, and annually thereafter. Therefore, the actual age is ½ year less than indicated on the graph

From measurements made in this manner growth curves for clams from various beaches have been constructed. Three curves presented here (fig. 14) were made from clams taken from beds at Copalis, Wash., and Cordova and Swickshak, Alaska. The data are given in tables 1 to 4, inclusive.

TABLE 1.—*Copalis: Adult razor clams, total length at time of formation of each ring, based on ring measurements*

Length, in centimeters, mid-value of class	Ring number									Length, in centimeters, mid-value of class	Ring number								
	1	2	3	4	5	6	7	8	9		1	2	3	4	5	6	7	8	9
0.60	18									8.00		23							
0.80	17									8.20		28							
1.00	11									8.40		21							
1.20	22									8.60		31							
1.40	31									8.80		28							
1.60	44									9.00		32							
1.80	53									9.20		32	1						
2.00	55									9.40		33	4						
2.20	58									9.60		31	8						
2.40	53									9.80		37	9						
2.60	33									10.00		12	22						
2.80	19									10.20		7	23	1					
3.00	16									10.40		2	49	1					
3.20	9									10.60			50	5					
3.40	13									10.80			53	3					
3.60	7									11.00			46	8					
3.80	5									11.20			45	10					
4.00	3									11.40			34	22	3				
4.20	1									11.60			34	52	2				
4.40		1								11.80			29	49	4	1			
4.60		1								12.00			10	63	22				
4.80		11								12.20			4	54	16	2			
5.00		1								12.40			2	45	37	5	1		
5.20		4								12.60			1	40	41	6	2		
5.40		2								12.80				21	74	15	4		
5.60		5								13.00				4	46	34	1	3	
5.80		10								13.20				3	30	37	10	1	
6.00		8								13.40				5	25	48	20	1	1
6.20		9								13.60				2	14	34	25	3	
6.40		11								13.80					6	31	32	12	2
6.60		5								14.00					7	20	27	15	1
6.80		10								14.20					2	4	19	12	2
7.00		10								14.40					1	8	15	12	3
7.20		11								14.60						4	9	6	2
7.40		15								14.80						1	6	7	1
7.60		22								15.00							1	2	4
7.80		14								15.20								1	2

TABLE 2.—*Cordova: Adult razor clams, total length at time of formation of each ring, based on ring measurements*

Length, in centimeters, mid-value of class	Ring number										
	1	2	3	4	5	6	7	8	9	10	11
0.10	28										
0.30	75										
0.50	35										
0.70	17										
0.90	2	3									
1.10		10									
1.30		15									
1.50		24									
1.70		37									
1.90		48									
2.10		52									
2.30		55									
2.50		66									
2.70		41	1								
2.90		29	4								
3.10		25	3								
3.30		14	6								
3.50		1	5								
3.70		1	15								
3.90		1	29								
4.10		1	33								
4.30			36								
4.50			33								
4.70			34								
4.90			38	2							
5.10			39	2							
5.30			38	1							
5.50			30	5							
5.70			22	7							
5.90			25	15							
6.10			14	12							
6.30			11	13							
6.50			10	20							
6.70			4	25							
6.90			2	21	1						
7.10				26	4						
7.30				32	5						
7.50			1	34	2						
7.70				32	8						
7.90				35	13	1					
8.10				31	15						
8.30				29	10	1					
8.50				17	12	1					
8.70				21	15	5					
8.90				11	20	3					
9.10				14	22	7					
9.30				7	25	5	1				
9.50				4	27	13					
9.70				3	33	11	1				
9.90				1	35	10	3				
10.10				1	32	15	4				
10.30					36	9	4	1			
10.50					22	20	3				
10.70					28	19	10	3			
10.90					11	22	12	2			
11.10					11	22	14		1		
11.30					9	28	15	3			
11.50					5	14	14	8	1		
11.70					3	20	9	10	3		
11.90						18	27	3	1		
12.10						16	27	16	5	1	
12.30						15	15	12	1	4	
12.50						18	22	14	5	2	
12.70						17	16	12	7	1	3
12.90						13	18	8	9	4	2
13.10						9	8	14	8	3	1
13.30						8	2	9	5	8	3
13.50						11	1	3	5	4	2
13.70						3	1	6	5	5	4
13.90						2	1	2	4	5	2
14.10									2	6	6
14.30									1	2	3
14.50									1	3	1
14.70										1	5
14.90										1	3
15.10											1
15.30											1

Table 3.—*Swickshak: Adult razor clams, total length at time of formation of each ring, based on ring measurements*

Length, in centimeters, mid-value of class	Ring number 1	2	3	4	5	6	7	8	9	10	11	12	13	14
0.10	62													
0.30	11													
0.50	32													
0.70	21													
0.90	11	1												
1.10	1	1												
1.30		9												
1.50		12												
1.70		17												
1.90		31												
2.10		55												
2.30		65												
2.50		68												
2.70		96	1											
2.90		65	1											
3.10		74												
3.30		42	4											
3.50		34												
3.70		31	4											
3.90		11	9											
4.10		7	8											
4.30		4	7											
4.50		4	12											
4.70		1	25											
4.90		1	11											
5.10			17											
5.30			31											
5.50			27											
5.70			28											
5.90			52											
6.10			35											
6.30			32											
6 50			46											
6.70			34											
6.90			39											
7.10			37	5										
7.30			46	2										
7.50			24	5										
7.70			20	8										
7. 90			25	3										
8.10			13	20										
8.30			9	15										
8 50			10	12										
8.70			5	18										
8.90			1	23										
9.10				18	1									
9.30				17	4									
9.50				13	2									
9.70				15	1									
9.90				13	4									
10.10				8	12									
10.30				11	8									
10.50				9	15									
10.70				12	20									
10.90				8	22									
11.10				8	16	5								
11.30				8	15	2								
11.50				3	23	8								
11.70					20	7								
11.90					15	11	3							
12.10					16	20	3							
12.30					14	19	4							
12.50					8	18	9	3						
12.70					7	30	14	5						
12.90					10	26	18	4						
13.10					1	24	14	10		1				
13.30					2	23	21	10	10	1				
13.50					2	10	23	16	9	3				
13.70						7	27	23	8	10	3			
13.90					1	5	24	25	16	9	5	2		
14.10						6	22	21	14	5	5	1		
14.30						5	14	18	16	13	6	4		
14.50						1	9	18	24	21	7	4	1	
14.70							6	22	13	17	12	5		1
14.90							2	8	13	16	16	4		
15.10						1	4	8	18	11	13	12		
15.30								4	12	17	13	3	1	1
15.50							1	4	12	11	6	6	2	1
15.70								4	7	13	10	6	1	
15.90								1	2	10	11	7	1	
16.10									3	2	8	8	2	1
16.30										4	6	4		1
16.50										2	4	6	2	
16.70											1	2		1
16.90											1	3	1	

Table 4.—*Growth in different localities*

Years	Copalis	Cordova	Swickshak
1	2. 04	0. 43	0. 38
2	8. 61	2. 38	2. 70
3	10. 87	4. 68	6. 41
4	12. 04	7. 73	9. 28
5	12. 81	9. 84	11. 47
6	13. 40	11. 40	12. 74
7	13. 84	12. 03	13. 70
8	14. 18	12. 57	14. 19
9	14. 50	13. 08	14. 63
10		13. 60	14. 94
11		14. 15	15. 25
12			15. 61
13			16. 12
14			15. 96

The Washington curve shows the fastest growth, followed by Swickshak and Cordova, in the order named. The first point on each curve represents the average size of the young clams from the respective beds during the first winter. The Washington clams reach an average size of 2 centimeters, in contrast to ½ centimeter for Alaska. This is due to the later spawning in Alaska and the earlier suspension of growth, due to the shorter season, which is about one-half as long as for the southern beds. The young clams of Alaska are very difficult to find during their first year. Plankton tows taken at Cordova on August 17, 1924, showed a large number of half-grown larvæ, which could hardly have settled soon enough to make appreciable growth before the water temperature dropped below the point where growth is possible.

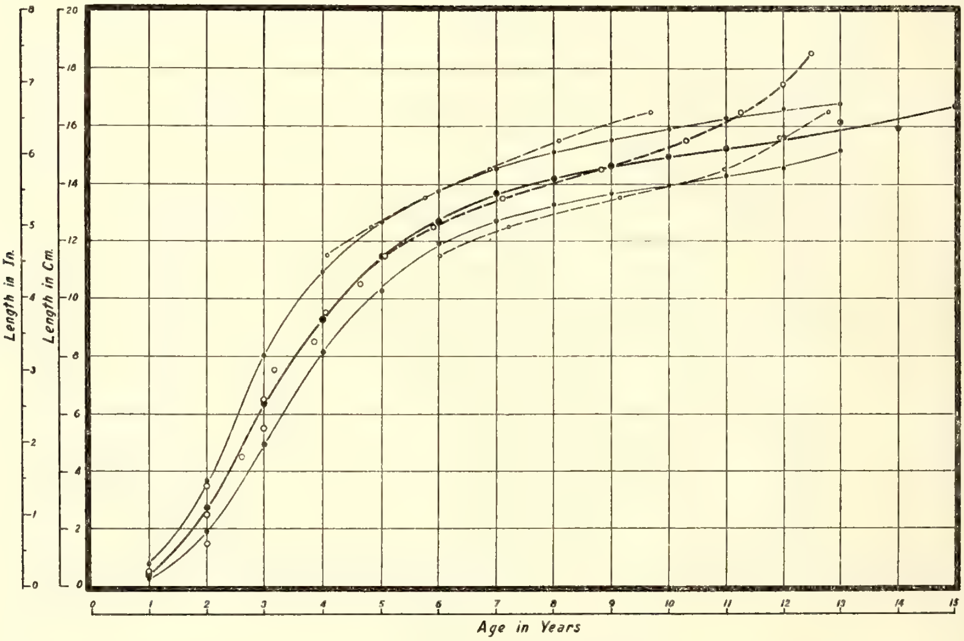

FIG. 15.—Swickshak clams. Graph showing the average length of each age (solid line) and the average age of each length (broken line). The latter is irregular in the first three years, due to the necessity of using one year as an interval of time. Center line shows the median or age, and the lines above and below show the 90th and 10th percentiles, respectively

While there is not a great difference in the final size of clams from various beds, there is a marked variation in the rate of growth during the first few years. As has already been stated, clams from the Washington beds reach maturity at about 10 centimeters in two years, while those from Swickshak and Cordova do not reach a similar size before three and four years, respectively. The legal size of 11.44 centimeters (4½ inches) is reached at the following ages: Washington, 3.5 years; Swickshak, 5 years; and Cordova, 6.3 years. The growing season in Alaska, as already mentioned, is roughly one-half as long as in Washington.

However, more definite data may show a closer correlation between the rate of growth and the length of growing season of the different beds, which in turn may be confined to clams below a certain size. The maximum for the Washington clams is about 12 years, while those from Alaska may reach an age of 17 or 18 years, but the large number of specimens necessary for an average to extend the growth curves to those ages are not available.

The ordinary growth curves, samples of which have been presented in Figure 14, are constructed from a table in which the average (median used) length of each age is calculated. With the same data used to calculate the values for the Swickshak growth curve the process was reversed, and the average age of each length class was determined (fig. 15 and Table 5) and a growth curve constructed from these figures (Weymouth, McMillin, and Rich. 1925). As the annual interval is very much larger than is convenient to use, the points at the lower end of the curve are irregular. The range was too small to calculate the tenth and ninetieth percentiles until the fifth year. Up to the age of five years the two curves might well be considered as coinciding; then the second "regression" (the average age for each length) tends to fall below the first, but later it rises and crosses it at about nine years, after which there is a distinct separation of the two curves. This shows that the correlation between age and size is less as the clams increase in age. In younger specimens size is a fair indication of age. A 2-year-old and a 4-year-old clam are greatly different in length, but the difference between a 9-year-old and an 18-year-old clam may amount to very little, with the possibility of the younger being the larger.

TABLE 5.—*Swickshak beach*

Length on age				Age on length			
Age in years	Percentiles			Length in centimeters	Percentiles		
	10	50	90		10	50	90
1	0.24	0.38	0.76	1.5		1.00	
2	1.94	2.70	3.52	2.5		2.00	
3	4.70	6.41	7.81	3.5		2.00	
4	8.13	9.28	10.94	4.5		2.00	
5	10.30	11.49	12.68	5.5		2.60	
6	11.92	12.74	13.76	6.5		3.00	
7	12.74	13.70	14.51	7.5		3.00	
8	13.27	14.19	15.11	8.5		3.16	
9	13.57	14.63	15.60	9.5		3.87	
10	13.94	14.94	15.93	10.5		4.05	
11	14.29	15.25	16.28	11.5		4.67	
12	14.53	15.61	16.61	12.5	4.09	5.03	6.04
13	15.19	16.12	16.78	13.5	4.85	5.94	7.25
14		15.96		14.5	5.77	7.12	9.15
				15.5	6.91	8.83	10.97
				16.5	8.08	10.03	11.94
				17.5	10.03	11.25	12.78

MATURITY

AGE AT MATURITY

During the summer of 1924 a large amount of fresh material was examined to determine the age and size at maturity. In some localities the specimens were taken from boxes on the cannery floors soon after they arrived from the beds; at other times they were dug especially for this purpose and examined on the beach. As the length of the clams used for this study varied from 7 to 12 centimeters (2½ to 4½ inches) the shells were very thin. The mantle was split along the midventral line, and the shell broken back to expose the interior. When the mantle is opened, the larger part of the body is seen to be composed of the foot, or "digger," which contains the gonads and in mature specimens before spawning is distended with a great mass of reproductive material. In immature clams the posterior part of the foot appears translucent, and through its walls the outline of the digestive tract can be seen. After a number of examinations a marked difference, apart from size, can be noticed between clams that have spawned out and those that have never formed reproductive material. The mature clams never regain the translucent appearance and some become very dark soon after spawning.

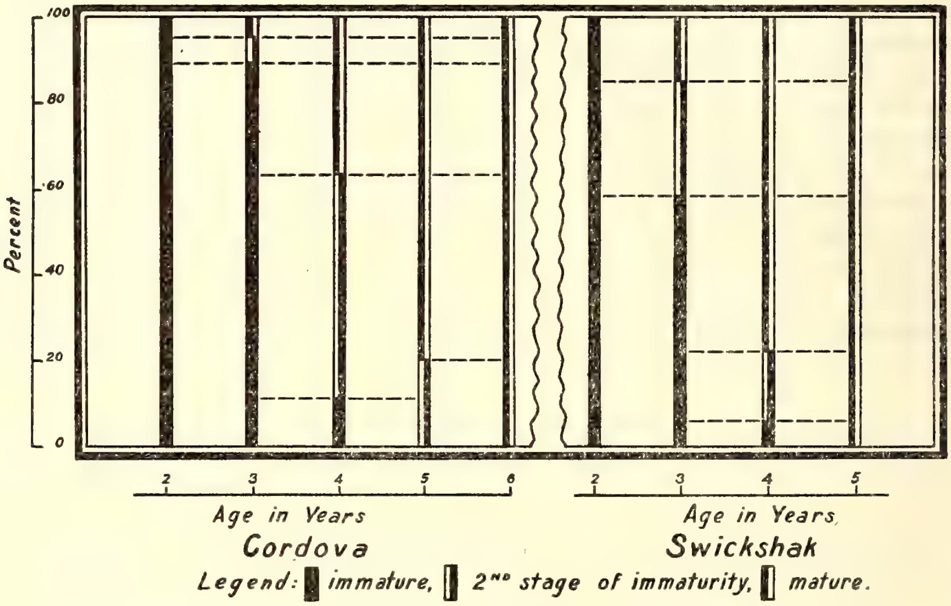

FIG. 16.—Showing the coming into maturity of small clams from Swickshak and Cordova, with reference to age. All are immature at 2 years of age and change gradually, to become completely mature at 5 and 6 years of age, respectively. Some pass through an intermediate stage the year prior to full maturity

In localities where maturity comes on at from 3 to 5 or even 6 years of age, there is a gradual changing over from the immature to the mature state. This makes a class between the obviously immature and the mature that can be distinguished accurately. For the sake of simplicity this intermediate stage has been called the "second stage of immaturity." It was first thought that the second stage of immaturity, as here explained, was a transient phase preceding complete maturity by a few weeks. Careful study, however, showed that this intermediate stage persists after the mature clams have spawned. Small egg strings or sperm-bearing masses are present in unchanged condition in late summer. Female clams have small elongate eggs, which do not change during the season. For these reasons it appears that those individuals passing through this stage remain in the same condition for the year prior to maturity. It is not known whether the reproductive products are held over the following winter or are resorbed.

Assuming that the stage of maturity is accurately determined in all cases (282 clams examined), the facts seem complicated. For the sake of clearness Figure 16 has been prepared from the data given in Tables 6 and 7. From it the process of coming into maturity is shown from the standpoint of age of the specimens. At Cordova all of the specimens examined in their second year were immature. In the next class a few (5.3 per cent) had become completely mature, and the same number had developed only partially—that is, had reached the second stage of immaturity. The following year class showed a few still immature and the mature ones of the former year still present, with their number increased by the addition of those in the second stage of immaturity of the former year. It is also shown that about 80 per cent of the fourth-year class passed out of the immature state, going into the two advanced divisions in the proportion of about 3 to 5, the smaller number becoming mature and the remainder advancing to the second stage of immaturity. No immature clams were found in the fifth-year class; 80 per cent were mature and 20 per cent were in the second stage of immaturity. This last figure is larger than the number of immature of the preceding year, but does not necessarily show that some individuals remained in the second stage of immaturity more than one year.

TABLE 6.—*Swickshak beach: Size of clams in different stages of maturity*

Length in centimeters	Age								
	3			4			5		
	Im$_1$	Im$_2$	M	Im$_1$	Im$_2$	M	Im$_1$	Im$_2$	M
7.5	22								
8.0	17								
8.5	36	7							
9.0	28	19		1		2			
9.5	12	21	5	3	3				
10.0	3	8	15	2	7	11			
10.5		1	5		3	15			1
11.0			1		2	18			2
11.5			2			14			1
12.0						8			3
Medians	8.78	9.55	10.30	9.83	10.32	11.16			11.75
Medians (total)	9.25			10.91			11.75		

TABLE 7.—*Cordova: Size of clams in different stages of maturity*

Length in centimeters	Age								
	3			4			5		6
	Im_1	Im_2	M	Im_1	Im_2	M	Im_2	M	M
7.0	3								
7.5	8			1					
8.0	17			5			1		
8.5	23	1		5	2				
9.0	12	1	1	6	27				
9.5	3	1		1	45	6	3	2	1
10.0		1	2		14	33		3	1
10.5			1			18		1	
11.0						6		4	
Medians	8. 60	9. 50	10. 75	8. 80	9. 67	10. 39	9. 67	10. 50	
Medians (total)	8. 70			9. 87			10. 06		

It must be remembered that each year class here used had a separate origin. The annual variation that exists may account for the apparently large number of 5-year clams that were not fully mature. In the vicinity of Cordova clams are taken from several beds, upon which the rate of growth is not equal, and the selection of some of the material used may have caused this discrepancy. All clams more than 5 years old are completely mature and spawn every year.

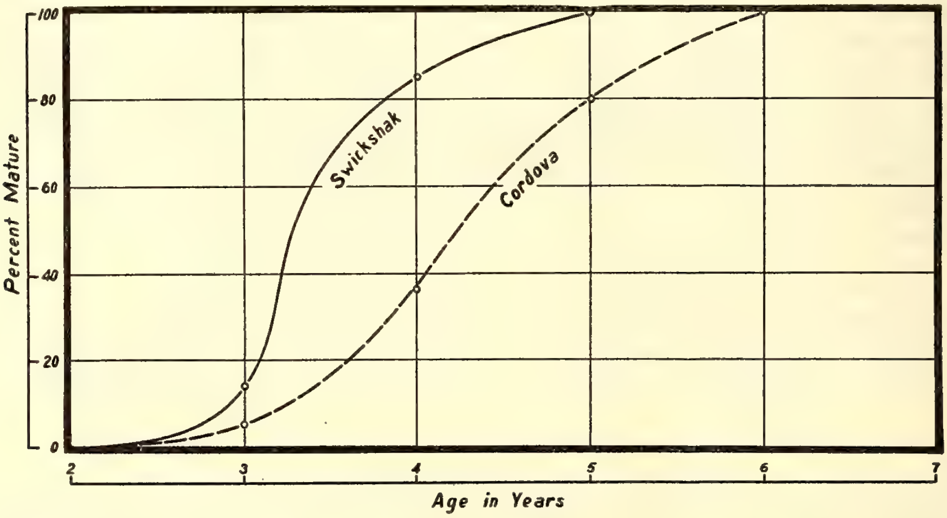

FIG. 17.—Showing the percentage of all clams mature at each age. For example, at Cordova of all clams 4 years of age 36.5 per cent were mature, while at Swickshak 85 per cent were mature at the same age

Figures obtained from 308 clams taken on Swickshak Beach gave more regular results. All 2-year-old clams were immature, but the following year over 40 per cent had passed out of this stage, 15 per cent becoming completely mature. In the fourth-year class 7 per cent were immature, while those in the second stage of immaturity numbered about 17 per cent. A great majority in the fourth year (over 75 per cent) and all specimens that were older were completely mature.

On the Washington beach no such gradual changing over is found. After the clams pass through their second winter they begin to develop reproductive material, and at 2 years of age spawning takes place. Doubtless there are some that do not spawn at this age, but none such have been found. The amount of the spawn cast is not large, but it does not differ in appearance from the products of the larger clams.

Thus it is seen that on some beds maturity comes on over a period of years. In such cases the age at which 50 per cent of the clams are mature (fig. 17) is taken as the age of maturity, and as thus determined is found to be 3.2 years at Swickshak, 4.2 years at Cordova, and 2 years at Washington. To summarize, about one-third of the clams at Cordova and one-half of those at Swickshak and all on the Washington beach become mature without passing through an intermediate stage. Since the clams at Cordova are slower in growth than those at Swickshak or Washington, it appears probable that more of them would pass through the second stage of immaturity, and this is found to be the case. The bearing of size upon maturity will be taken up in the following section of this report.

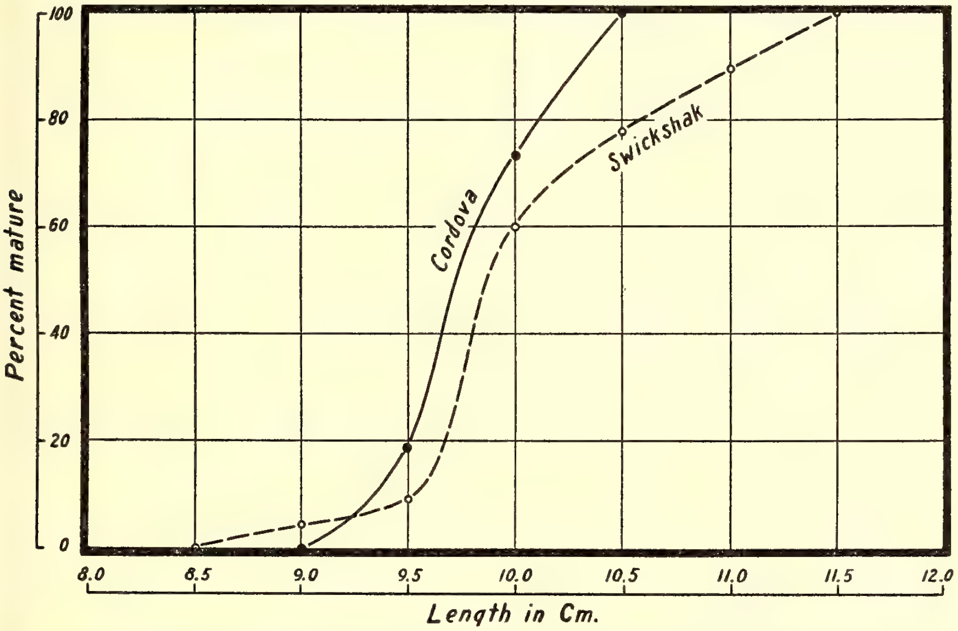

FIG. 18.—Showing the percentage mature at each interval of length

SIZE AT MATURITY

The relation of size to maturity has been treated in the same manner as age (fig. 18). The percentage of each stage of maturity in each class interval of length was calculated and plotted. At Cordova no mature clams of less than 9 centimeters were found, and all clams more than 10½ centimeters were mature. The size at which 50 per cent were mature (9.75 centimeters) was taken as the size at maturity. At Swickshak clams are first mature at 8½ centimeters, and all above 11½ centimeters are mature, maturity (50 per cent) being at 9.91 centimeters. All clams from the Washington beach spawn when they are 2 years old.

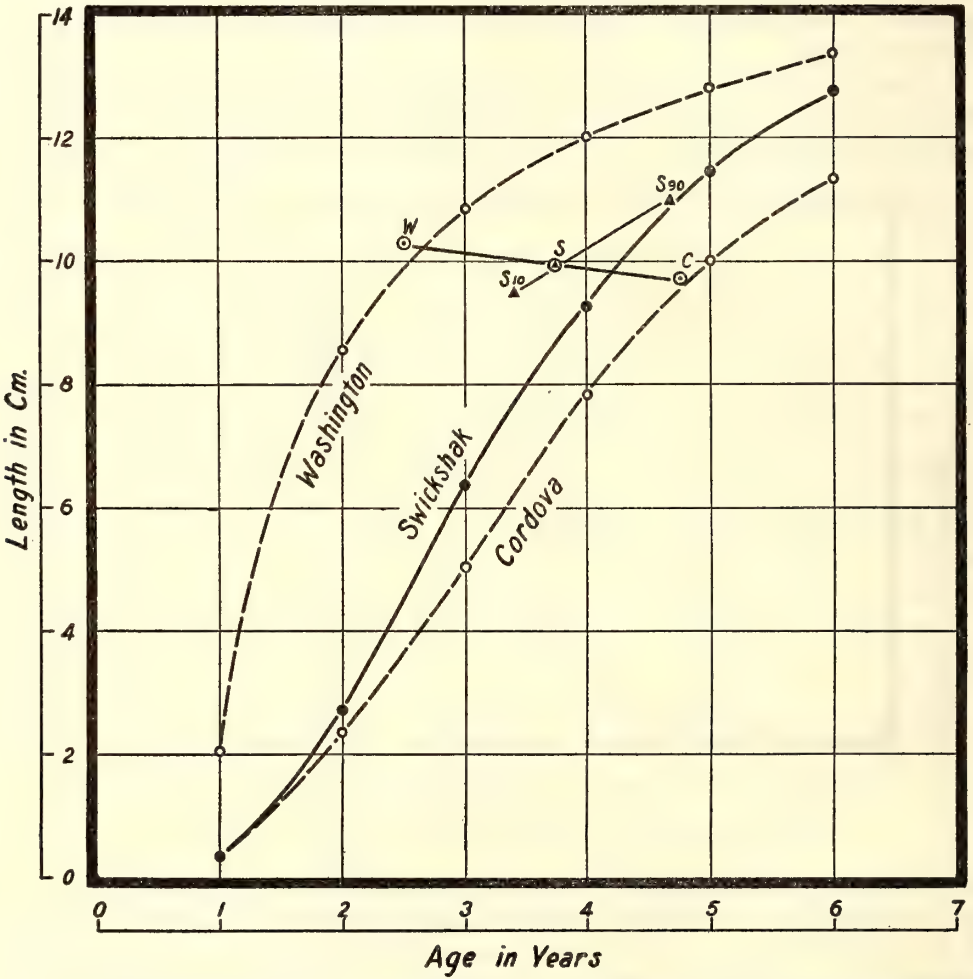

FIG. 19.—Showing portions of three growth curves and points at which 50 per cent, by age, and 50 per cent, by size, are mature on each bed (points *W*, *S*, and *C*). For the Swickshak material, S_{10}, S, and S_{90} represent the points at which 10, 50, and 90 per cent, respectively, by both age and size, become mature

Since all mature at the same age, the median length of these at spawning time has been taken as the size at maturity.

Thus in order of size the lengths at maturity on the different beaches are as follows: Cordova, 9.75 centimeters; Swickshak, 9.91 centimeters; Washington, 10.30 centimeters. At the rate at which the Washington clams were growing at this age (1.54 centimeters in three months) this difference amounts to one month's growth.

It must be remembered, in comparing these lengths with possible size limits. that at the above lengths but 50 per cent are mature. A recommended size limit is intended to provide opportunity for all individuals to spawn at least once.

RELATION OF AGE AND LENGTH TO MATURITY

The comparison of the results of the last two sections throws an interesting light on the process of maturing on the various beds of the Pacific coast. From a study of Table 8 and Figure 19 we see that there is a wide difference in age at maturity, but there is a close agreement in size. While the differences in size are small in comparison with those of age, an examination of the data shows them to be orderly and significant. Clams from beds where growth is slow, while older at maturity, are also smaller. The Washington clams, which show the most rapid growth, are the youngest but are largest at maturity; conversely, those at Cordova which show the slowest growth are the oldest but the smallest.

QUANTITATIVE MEASURES

A quantitative measure of the respective influences of age and length may be obtained by analysis of the figures given in Table 8. Between the youngest and the oldest there is a difference of 2.2 years, or, compared with the average of the three ages (3.1 years), a variation of 71 per cent. In contrast with this we have a variation of 0.55 centimeter in length, which, compared with the average length (10 centimeters), gives but 5.5 per cent. Therefore, in the process of maturing an increase in size of 1 per cent accompanies the same sexual development as an increase in age of 13 per cent.

TABLE 8.—*Age and length at maturity*

Locality	Maturity	
	Age	Length
Washington	2.0	10.30
Swickshak	3.2	9.91
Cordova	4.2	9.75

The data of Table 8, plotted in Figure 19 as line *W–S–C*, show the influence of both age and length on maturity. If age alone determined maturity, this line would be perpendicular and clams from all beds, while varying in size, would mature at one average age. If size alone determined maturity, the line would be horizontal. The age would vary, but the size would remain constant. From this line another ratio may be obtained by comparing the average relation of age to length and this same relation in respect to maturity. For example, from Figure 14 (p. 218), on the Swickshak curve near the size of maturity (3 to 4 years of age), one year's growth is equal to 2.89 centimeters, or, using this proportion, 0.346 of a year equal 1 centimeter in length. Like figures obtained from Washington and Cordova are given in Table 9. From the maturity line (fig. 19, line *W–S–C*) it is found that a variation of 2.25 years corresponds to a variation of 0.55 centimeter, which gives the following values: 4.10 years equal 1 centimeter; 1 year equals 0.244 centimeter.

Table 9.—*Relation of rate of increase of age and length at maturity*

Locality	Value of 1 year in centimeters	Value of 1 centimeter in years
Washington	2.26	0.442
Swickshak	2.89	.346
Cordova	2.17	.460
Average	2.44	.416

The figures given immediately above are comparable with the averages of Table 9. In growth, therefore, one year corresponds to 2.44 centimeters, but in maturity one year corresponds to 0.244 centimeter. The influence of a year in growth is thus ten times as great as in the process of maturing; or, from the standpoint of size, 1 centimeter corresponds to 0.416 year in age, but in maturity 1 centimeter corresponds to 4.10 years. The influence of a centimeter in growth is thus one-tenth as great as in the process of maturing. The ratio (1 to 10) thus obtained compares very favorably with that above (1 to 13), when the differences in methods are taken into account.

MATURITY IN OTHER FORMS

The relation of age and length to maturity given for the razor clam does not hold in all forms. The work of Thompson (1914) on the halibut shows that these vertebrates mature at nearly the same average age in different localities, while the average size varies quite widely. However, there is a difference in average age at maturity which, although slight, may be accounted for by the difference in average size. For example, fish from Hecate Straits mature at an average of 12 years of age and 40.7 inches in length, while those from Kodiak Island Banks mature at an average of 12.3 years and 35.4 inches. Thus, there is a variation in age of 0.3 year in 12, or 2.5 per cent, and in size of 5.3 inches in 35.4, or 15 per cent. The conclusion is, then, that a difference of 15 per cent in size at maturity between these two banks is accompanied by a difference of 2.5 per cent in age, which shows in this form that age and length influence maturity in the ratio of 6 to 1, age being the more important.

We offer no explanation for the maturing of halibut according to age and of clams according to size. Figures for other species are not available. The work of Baldwin (1921) and Crampton (1908) give data on the size and age of boys and girls at maturity, which further analysis may show to be similar to one of the above cases.

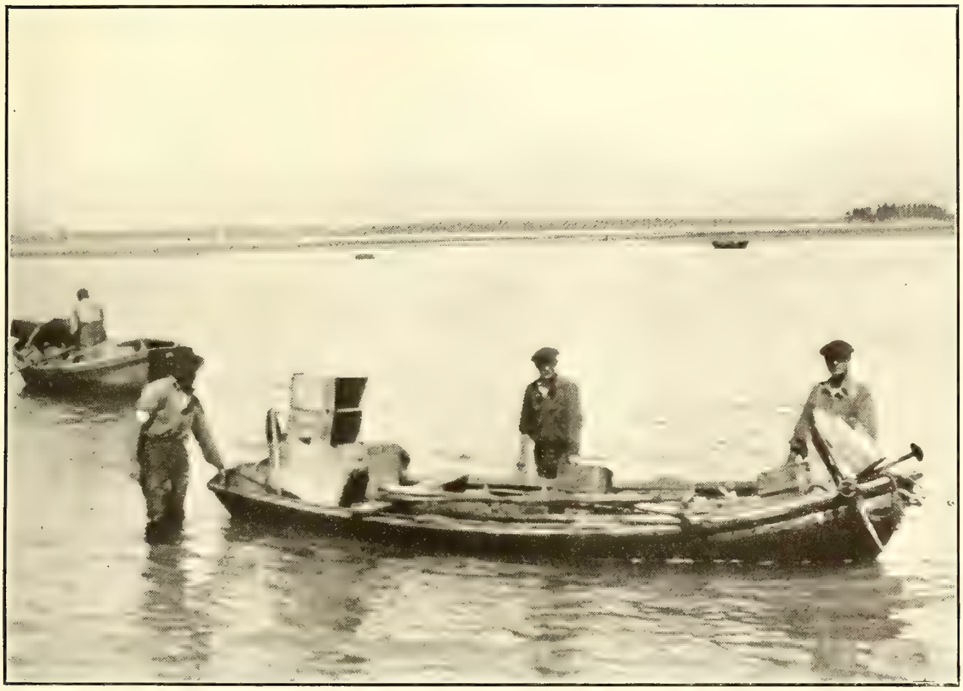

Fig. 20.—Rising tide, Snug Harbor beach

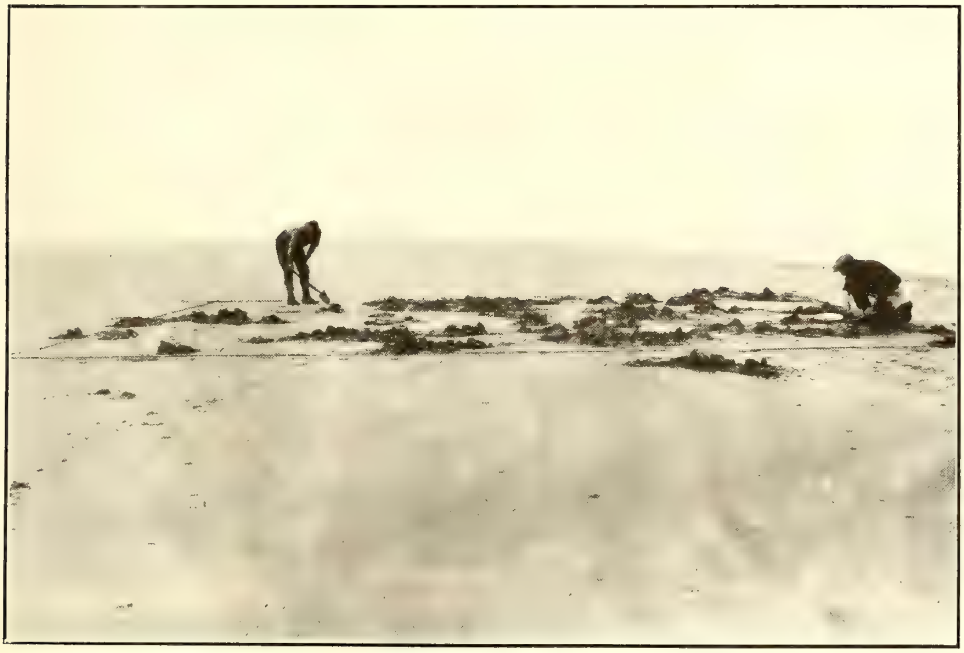

Fig. 21.—Digging marked area, Copalis beach

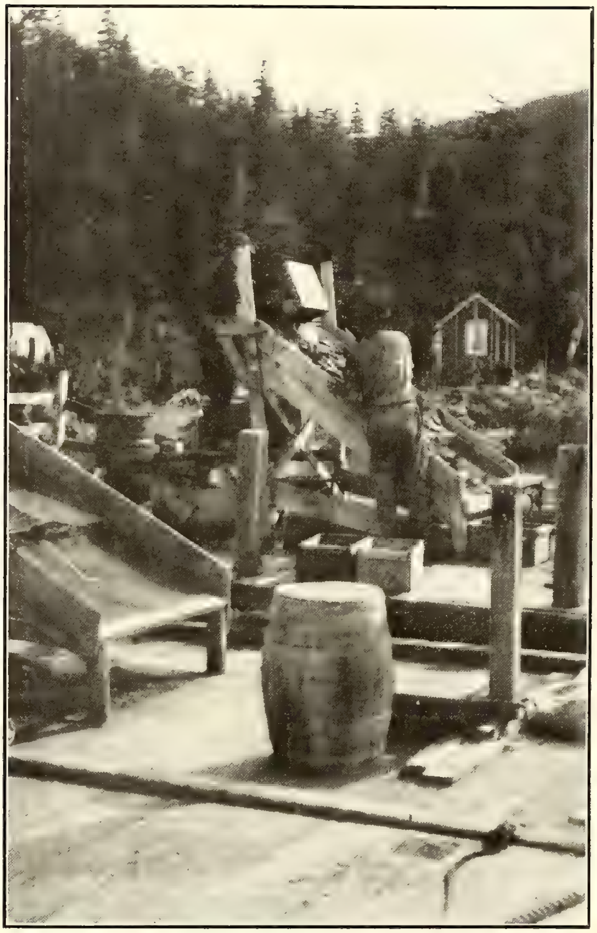

FIG. 22.—Weigh screen, near Cordova

BEACHES

No attempts have been made by the writers to explore areas that were not being exploited at the time the work was carried on in the field. It is impossible to find the unit population of any unit area, and in most cases it is difficult to get anything but a very rough idea of the size of the clam-producing beds. On undepleted beds the same area can be dug over on several consecutive days without apparent decrease in the day's catch, a fact which makes an accurate census impossible. Thus indications of depletion can not come from either a census or a survey of the beach, but, as we shall later see, show up quickly in the average size of clams in the commercial catch and in the average "dig" per man.

The clam-producing areas of the Washington and Oregon beaches can readily be measured. The beach is uniform in width, and the area exposed varies with the tide. The Alaska beds, on the other hand, are variable. Those in the vicinity of Cordova have been built up by sand brought down by the Copper River. They are made up of an intricate series of bars and channels which change their location at irregular intervals. In fact, the whole topography of the clam-producing area changes from year to year. Beds that are under several feet of water at the lowest tide of one season may be accessible to digging the next, and some high bars may be entirely submerged.

Swickshak beach changes less by shifting of bars and channels. The bottom slopes gradually, and the offshore water is very shallow, giving a wide intertidal zone. Since this beach is so flat, the height of tide governs the area exposed; on one spit it was estimated that a change of 1 foot in the tide was accompanied by a variation of 40 acres in the area of beach exposed. Owing to this, only rough estimates can be made of the areas.

The condition of the Snug Harbor beds, lying between Chisik Island and Harriet Point on the west side of Cook Inlet, is more like that at Swickshak than at Cordova. The tidal range over these beds is greater than elsewhere. Since the beach slopes very gradually, it is wide, the tide going out nearly 3 miles in one place. It was estimated that about 1½ square miles of beach were being dug during the summer of 1923. While this bed is not constantly being changed by the shifting of bars and channels, as at Cordova, portions of it are seriously menaced at times by deposits of glacial silt, which covers the beds and destroys the clams.

COMMERCIAL CATCH

As we have mentioned before, overfishing shows up in two ways—first, by the small size of clams taken, and, second, by the reduced average catch per man. On new beds, such as Swickshak in 1923, nearly all the clams taken were more than 5 inches in length. The same is true of the early digging at Cordova and for many years on the Washington beaches. On the northern beds the large clams appear to be very inactive, sometimes remaining with the siphon extended until dug. Therefore the large clams, on the whole, are more easily found and taken than the small ones. It takes as long to dig a small clam as a large one, and the result of taking them is apparent in the reduction of the average daily catch. On Washington beds, during 1924, the commercial diggers were able to get fair " digs " on but three tides of each " run " (two weeks), unless storms interfered, in which case the whole run was lost. The average size of the clams was small, being less than 4½ inches. A large part of the catch had never spawned. Many were lost through the screens at the weigh sheds, and still more were thrown out by the cleaners because of their small size. Although the enemies of conservation explained the reduced pack as the result of an " off year," such a condition points to serious depletion.

The same was true at Cordova in 1924. The diggers took every clam that showed, regardless of size, and the cannerymen, in their turn, purchased anything that was offered. Many of the clams were too small to be used to advantage and would have doubled in weight by another year. Only serious results can be expected from such treatment. Since the beginning of canning in Alaska in 1916 Cordova has produced between 80 and 90 per cent of the entire clam pack. The history of the pack is instructive (see fig. 23). After the opening of the beds in 1916 production leaped to approximately 50,000 cases in 1917 and 1918, and then rapidly dropped off, until only 1,600 cases were packed in 1921. This was in part caused by economic conditions, but the chief factor was the scarcity of clams, a number of operators claiming that the beds were completely exhausted and that it was unprofitable to attempt to pack. The demand for canned clams, however, led to exploration, and new beds were found adjacent to Cordova of such extent as to more than double the clam-producing area. Exploration to the westward at this time also led to the opening of Snug Harbor and later the beaches near Kukak Bay.

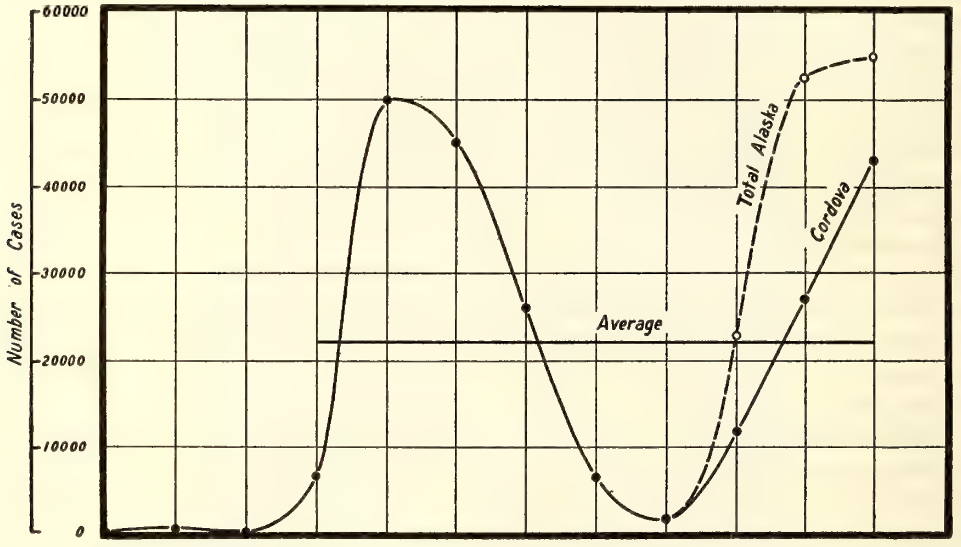

FIG. 23.—Showing the total clam pack of Alaska to date. Data from the " Pacific Fisherman "

With the increased supply of clams the pack at Cordova again rose to 27,000 cases in 1923. The pack for 1924 was in excess of this, or about 43,000 cases. This expansion has been obtained by the entry into the field of one new cannery and a material increase in the number of diggers. The fact that in 1924 twice the area of beach and more than twice the number of diggers produced but little more than four-fifths of the number of cases packed in 1917 is in itself clear evidence that the beds have been overdug. If more proof is needed, it is furnished by the distinctly smaller average size of clams taken and the admittedly larger proportion of undersized clams. The clams naturally reach as large a size at Cordova as elsewhere. At Swickshak, in 1923, a clam less than 5 inches long seldom reached the cannery. We have only to contrast this situation with that at Cordova to realize how the intensive digging, by taking the older and larger clams, has reduced the average size.

If the entire pack of Cordova had been uniformly distributed over all the years from 1916 to 1924, inclusive, this average pack would have amounted to 23,000 cases. From the present state of the beach it is evident that 23,000 cases per year is in excess of what the beds can support. Perhaps 15,000 cases might be taken annually without serious depletion, possibly but 10,000, but the data at hand is insufficient to determine this.

It is clear from our investigations that a yield approaching, area for area, that of the Washington beaches is not to be expected of those in Alaska. This can not be too strongly emphasized, as estimates or expectations based on the production of the Washington beaches, with which most of the operators and diggers are familiar, must inevitably lead to disappointment and disaster. In the first place, the set of young on the Alaskan beaches has never equaled or even approached that on the southern beds. As has been stated, at Copalis in the fall of 1923 the small clams averaged over 1,400 per square foot. During 1923 and 1924 a careful search for the young on all the producing Alaska beds did not reveal a single location where a square foot would regularly yield even one small clam, and only a few of the diggers have even noticed these young, although acquainted with them in the south.

Secondly, the growth is far slower in Alaska. We have shown that a length of 4½ inches is reached in about three years at Copalis but in six years at Cordova. Because of this the recuperative power of the northern beds will be far less and the effects of protection will be slower in appearing. For instance, in a sample of 152 clams over 4½ inches in length, taken at one of the canneries during the present season (1924), 109 were hatched prior to the beginning of digging in 1916; of the remainder 23 were hatched in 1916. In other words, 87 per cent of the clams now being taken were in the beds by the summer in which canning started. Even if we include the undersized clams packed in the last few years, well over 90 per cent of the pack has been of clams already living when canning started, and the course of the industry would have been little altered if all spawning had ceased at that time. Thus, to an alarming and unrecognized degree, the industry has been consuming its capital. When the reduced spawning, resulting from the reduced number of spawners, begins to make itself felt the pack, even though materially reduced, can only be maintained by the ruinous process of drawing upon that part of the capital which has never given interest—the young before they have spawned.

It is therefore clear that the taking of clams must be drastically reduced or the industry will vanish before the prohibitive cost of obtaining the few scattered remaining clams. If this occurs, it must be remembered that its restoration is a long process. The first generation would not be numerous enough to sustain a commercial fishery, and for all of them to spawn would require six years, although part of them spawn at four or five years. For the second generation to reach even the minimum size of 4½ inches would require another six years. Thus no relief could be had before 12 years, and a material increase would of course require several years more.

In the face of this situation it may prove that the present size limit is insufficient to maintain the beds. It is desirable that the clam industry be made a permanent one, and the present size limit should be given a fair trial before additional and more complicated regulations are imposed. Should this fail to reduce the pack to a level that the existing beds can support, other measures remain. The size limit might be increased to 5 inches. This would practically close some of the beds in which the average size has been greatly reduced by intensive digging, and thus automatically afford protection where most needed.

It has been claimed by some that any size limit would be unsatisfactory. First, the size of the clam could not be known before it is dug, and the thin shells of the undersized clams probably would be broken by the digging operation and the clam eaten by gulls if left on the beach. Second, a size limit would be difficult of enforcement. The writers have considered both of these arguments and fail to find that either is cogent. If the individual " digs " of the men are examined, it will be found that many consist entirely of large or at least legal-sized clams, showing that it is quite possible to avoid the small clams and still make good " digs," for it will be found that these men usually have more clams than the average. The present regulation permits a small percentage of undersized clams, which would take care of those cases where small clams are accidently crushed in digging. Observation of many clams has shown that broken shells are repaired to a far greater extent than might be expected. From experience on every beach the writers feel sure that any person taking more than 1 per cent of undersized clams is either a new and totally inexperienced digger or does so by intention and not by accident. It requires no argument to show that, with the clams in the shell on the cannery floor for periods up to 24 hours, inspection of sizes would be easy.

Another method would be to close certain districts for a year or a term of years. This would be more difficult of enforcement and might affect some canneries more than others, but it would be effective if the necessity arose. A closed season has been proposed on the assumption that it would reduce the pack. It is open to the objection of discrimination, such a limitation of season falling more heavily upon the small local firms, at present operating over a long season, than upon the larger canneries, which now operate during a short season only. The same season, also, would not apply to all districts, and further investigation would be needed to regulate this, which would result in confusion. It is possible that such a regulation would only result in more intensive fishing during a shorter season and would bring about no reduction in the total pack.

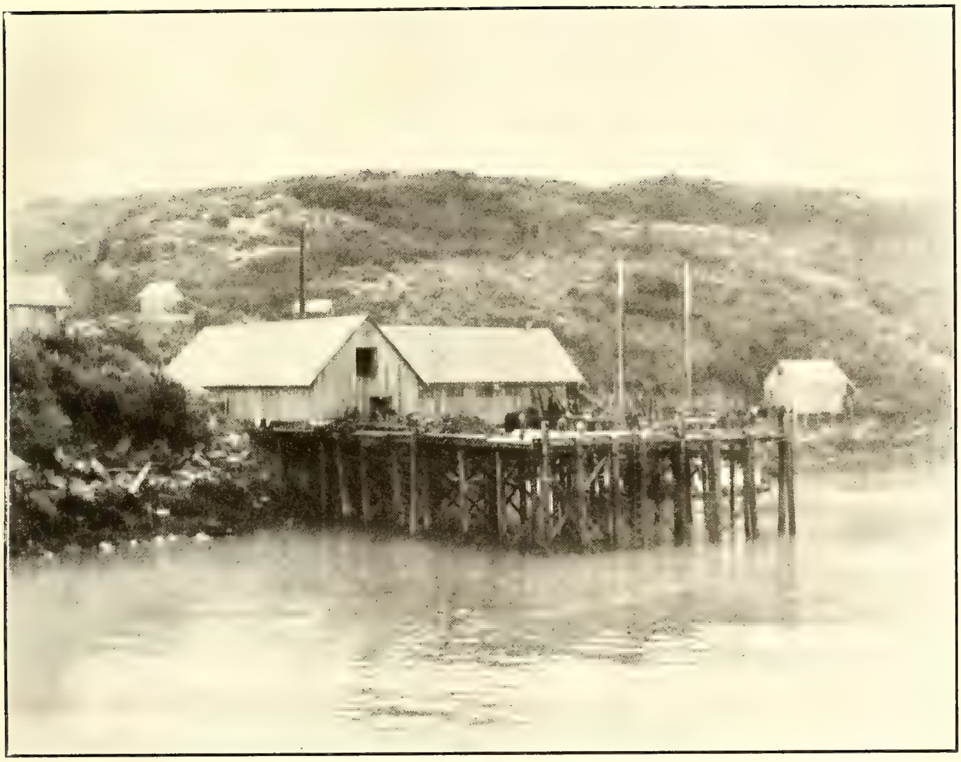

Fig. 24.—Cannery at Kukak Bay

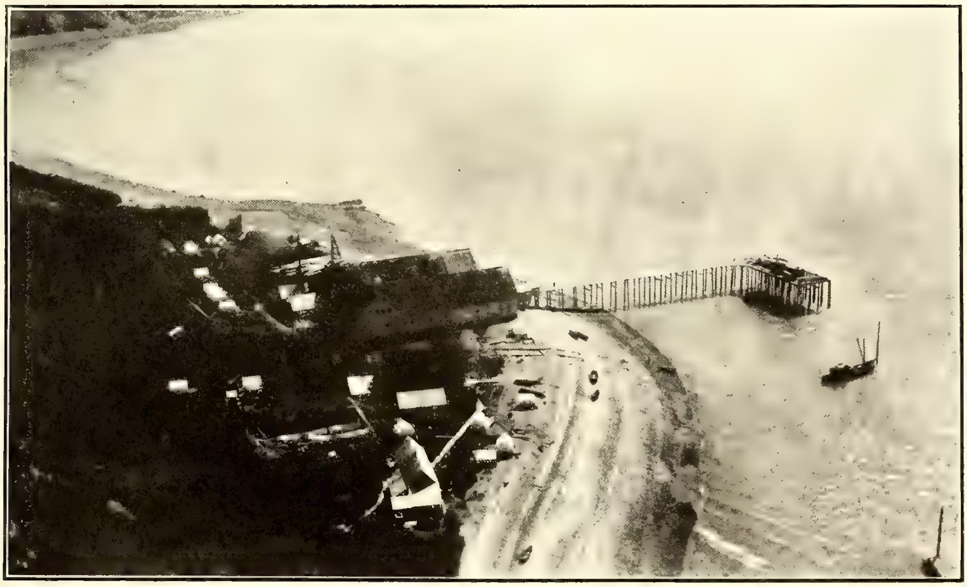

Fig. 25.—Cannery at Snug Harbor, Chisik Island

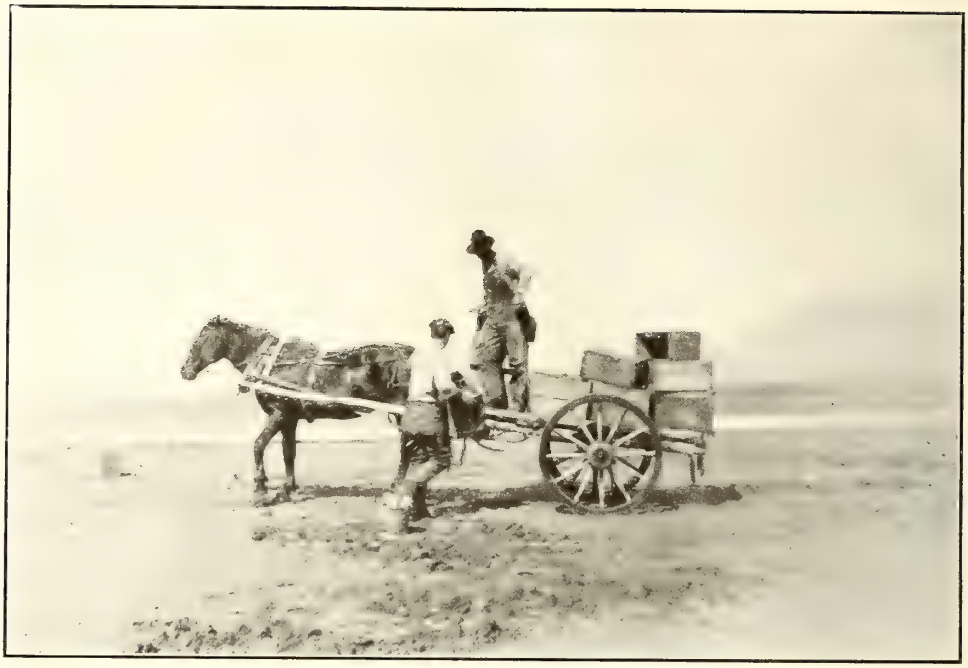

Fig. 26.—"Pickup" wagon, Snug Harbor

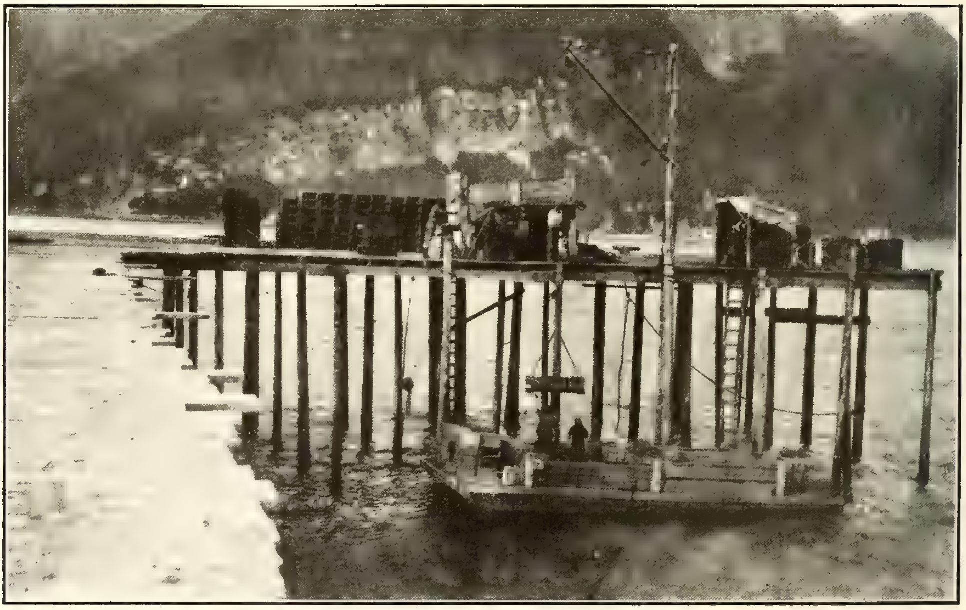

Fig. 27.—Unloading clams, Snug Harbor cannery

SUMMARY

The present paper deals with the Pacific razor clam (*Siliqua patula*), a form of commercial importance along the entire northwest coast from Oregon to the Alaskan Peninsula. This is considered to be a single species throughout this range, the observed variations being due to environmental conditions.

Spawning on the Washington coast takes place between the middle of May and the middle of June, while in Alaska the spawning season is less sharply marked and occurs from the first of July to the middle of August. Spawning apparently takes place on a sharp rise of water temperature at about 13° C. (55.5° F.).

The larval stage endures about eight weeks, during the greater part of which time the young are in the surface sand. At the end of this period they appear in the intertidal zone as small clams, differing little from the adult in structure or habits. The "set" of these young is sometimes enormous on the Washington coast, but is never so heavy in Alaska. The mortality of the young during the first two years may be very heavy. A yearly census for the purpose of determining the success of each spawning year and its future effect on the commercial catch is recommended.

The growth of the adult on various beaches has been determined from data obtained by a study of the annual rings. Norms are presented to show the relative rates of growth at the three places where the industry is most important.

The size and age at maturity has been determined by a study of the young clams. The size at maturity on all beds is in close agreement, but the age varies greatly. The relative influence of age and size on maturity has been determined mathematically and compared with other known forms.

The only feasible criteria of overfishing are, first, the reduction in the average size of clams in the commercial catch and, second, the reduction in the average daily "digs" per man. A size limit has been proposed which, by protecting the small, immature clams, would prevent serious depletion of the beds now greatly overdug.

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FISHES OF THE REPUBLIC OF EL SALVADOR, CENTRAL AMERICA

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INTRODUCTION

This report is based upon collections made in El Salvador during the last half of January and the first half of February, 1924, by Fred J. Foster, superintendent of the United States Bureau of Fisheries station at Neosho, Mo., and the writer. This visit to El Salvador was made in response to a request of the Government of that country to the Government of the United States for the services of one or more specialists to examine principally the fresh waters to determine the status of the fisheries and to study their needs. The United States Commissioner of Fisheries thereupon detailed Mr. Foster and the author to proceed to El Salvador for that purpose. A report embodying the economic phase of these studies has been prepared by Mr. Foster and the author; it is sufficient to state here that fish are very scarce in most fresh waters and that the quantity taken annually appears to be very small. Two brief collecting trips were made to salt water, and there, too, fish appeared to be rather scarce. It is well understood, however, that the abundance of fish in salt water usually varies greatly with the season, and the results obtained from the two short visits made are not sufficient to form the basis for any conclusions.

The scarcity of fresh-water fishes may be due mainly to the absence in the past of measures of protection, and in certain waters probably to the liberation, through earth disturbances, of poisonous gases. Fishing has been carried on at all seasons of the year, and such destructive methods as the use of dynamite and plant poisons appear to have been used frequently. Fishes of nearly all sizes are taken and marketed. Individuals 75 millimeters in length, belonging to species that reach a length of 300 millimeters and more, are taken and sold in the markets. Even the top minnows (Pœciliidæ, locally known as "chimbolas") are sold both in the fresh and dried state.

El Salvador is the smallest of the Central American Republics, having an area of 34,126 square kilometers, or about equal in size to the State of New Jersey, and it is the only one of these republics which is wholly within the Pacific drainage and which does not also border on the Atlantic Ocean. The climate, of course, is tropical, but the country is largely mountainous, and a considerable variation in temperature, according to altitude, exists. This country, like most tropical countries, has a wet and a dry season. The wet season extends from about May to November, and the dry season occupies the balance of the year. The wet season is referred to by the inhabitants as winter and the dry season as summer.

The Republic, from an agricultural standpoint, is rich, and, exclusive of Haiti, it is said to be the most densely populated country of the Western Hemisphere. The great mass of the people are Indians, who live a simple life, have little, and whose wants seem to be satisfied easily. Spanish, the State language, is spoken everywhere.

El Salvador, although small, is well supplied with fresh-water lakes and streams. The Rio Lempa, a comparatively large stream, lies mostly within its borders. Lake Guija, with an area of 300 square kilometers, lies on its border, partly in El Salvador and partly in Guatemala. It appears to be quite rough a large part of the time, and plant growths were found only in protected coves. Soundings taken

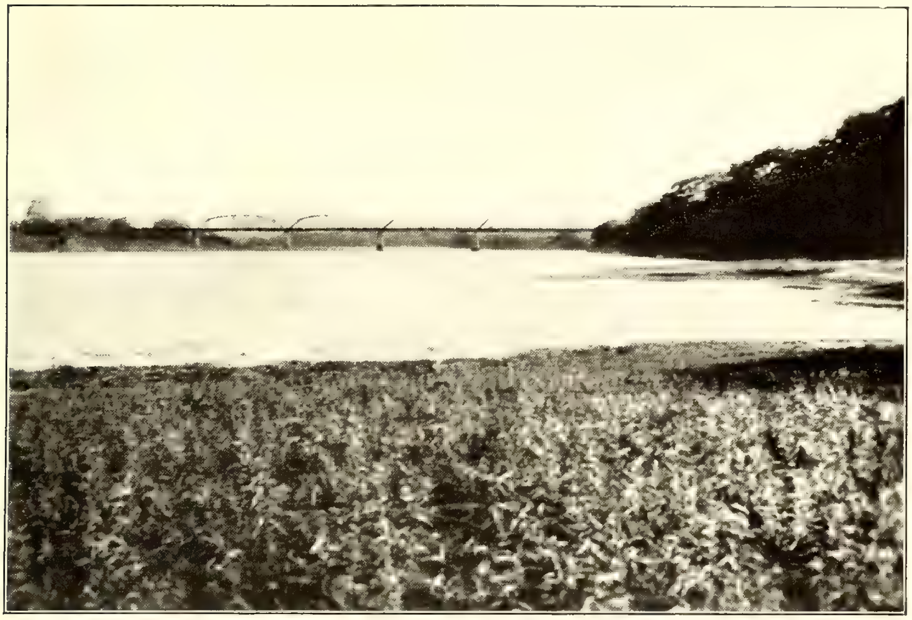

FIG. 1.—Rio Lempa at San Marcos, with railroad bridge in the background

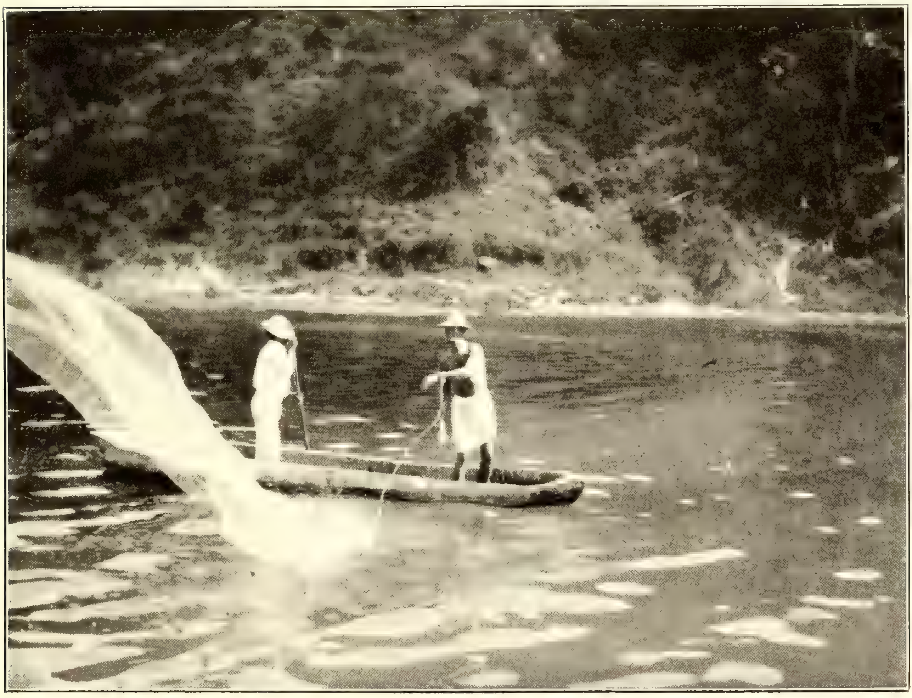

FIG. 2.—Natives fishing with a cast net in Lake Ilopango

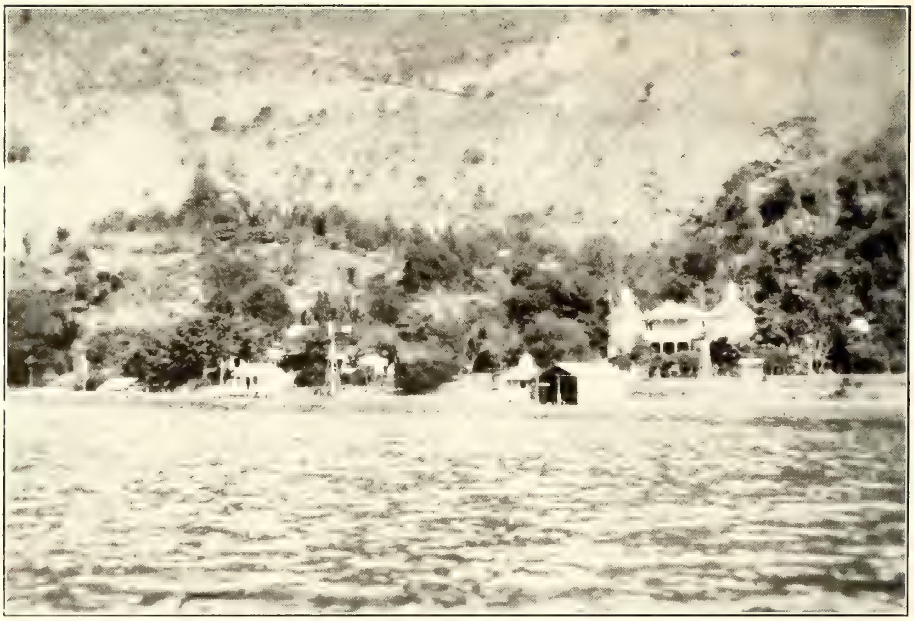

Fig. 3.—View from Lake Coatepeque, showing buildings along the shore and a steep mountain side in the background, with zigzag trail

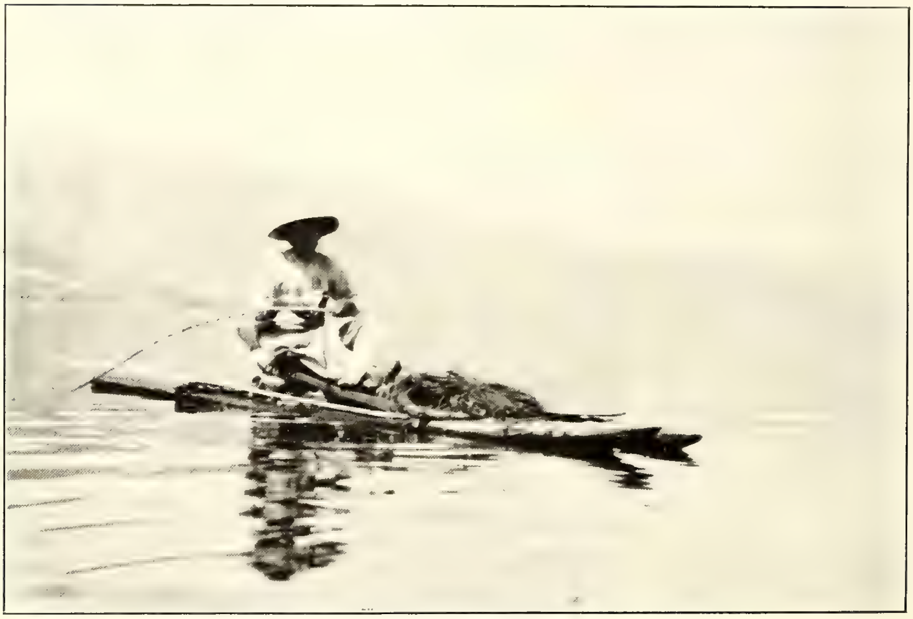

Fig. 4.—Indian fishing in deep water from a balza on Lake Coatepeque

offshore varied from 4.5 to 16 meters. Lake Ilopango, with an area of 70 square kilometers, and Lake Coatepeque, with an area of 30 square kilometers, are beautiful, deep, clear bodies of water having considerable vegetation along the shores, some of the plants growing at a depth of 7 meters or more. The plants consist largely of Chara, Ceratophyllum, and Naias, the plant growing at the greatest depth being *Naias marina*. Lake Ilopango has an outlet, but Lake Coatepeque has none, and the water in the latter has a slightly salty taste, the sodium chloride content, according to an analysis posted in a local hotel, being 0.4465 grams per liter. The maximum depth of Lake Ilopango was not obtained, as the lake was too rough at the time of our visit to make vertical soundings with the apparatus at hand.

The greatest depth found in Lake Coatepeque was 83 meters. Hook and line fishing from the native raft, the "balza," is carried on in this lake to a depth as great as 30 meters, and the species taken at the greatest depth is *Cichlasoma motaguense*. In Lake Ilopango food fishes are scarcer than in any other lake visited. This may be due to overfishing stimulated by its proximity to San Salvador, where fishes command a fancy price.

Lake Olomega is another lake of considerable size, having an area of 20 square kilometers. This lake is shallow, having an average depth of scarcely 2 meters, and the water is turbid. Vegetation is abundant along the shores where they are not too rocky. The country also has quite a number of smaller lakes, among which Metapan,[1] Ahuachapan, Chalchuapa, Zapotitan, and Chanmico were visited. Among these lakes Metapan and Ahuachapan are shallow and afford some of the best fishing found in El Salvador. Chalchuapa and Chanmico are quite deep and food fishes are scarce, while top minnows are very abundant. Lake Zapotitan covers considerable territory, but it can scarcely be considered more than a swamp that is so densely overgrown with vegetation that a boat can not be used.

The Rio Lempa, the largest river in El Salvador, was visited at Suchitoto and San Marcos, and collections were made at each place. Collections were made in two of its tributaries also, namely, in the Rio del Desague near Lake Guija, of which it forms the outlet, and in the Rio Sucio at Sitio del Niño. In the Rio San Miguel, a much smaller stream than the Lempa, a collection was made at San Miguel. In the Rio de Paz basin collections were made in the Rio Molino near Ahuachapan and in the Rio Pampe near Chalchuapa. One day was devoted to collecting in the small mountain streams near San Salvador, some of which empty into Lake Ilopango and some into the Rio Lempa.

All the streams of El Salvador that were seen are rocky, having rapids and comparatively large, deep stretches between the rapids. Sand and gravel are found only occasionally, and collecting with drag nets is difficult. The natives use cast nets both in the streams and in the lakes. Hook and line fishing also is engaged in in some localities.

The temperature of the water at the surface in the different lakes and streams ranges from about 74 to 83° F., the average being close to 78°. The difference between the bottom and the surface temperatures in the lakes is small. In Lake

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[1] In the vicinity of the city of Metapan is located a group of lakes known as "Laguna de Metapan," which are all connected during the rainy season but which become separated during dry weather. The collections reported in this paper were made in the small division of the Laguna de Metapan located nearest the city of Metapan.

Coatepeque, for example, at a depth of 83 meters at 8.20 a. m., the temperature was 72.5° F., while at the surface at the same time and place it was 74°; in Lake Ilopango, at a depth of 15 meters, the temperature was 80° F., at 2.30 p. m., and at the surface at the same time and place it was 81°; and in Lake Guija, at a depth of 16 meters, the temperature at 11 a. m. was 74.5° F., while at the surface it was 76.5°.

Fish, due chiefly to their scarcity, sell very high in comparison with other foods, bringing a better price than fresh fish do in our inland markets. The fish, furthermore, are usually small and far from the choice supply seen in our markets. Many fish are marketed in the dry state, having been sun cured without the addition of salt or any preservative. This stock, too, finds ready sale. The species sold chiefly in the dried state are the catfishes, locally known as "bagre"; the top minnows, "chimbolas"; and the characins, "sardina" and "plateada."

No collecting worthy of the name had previously been done in El Salvador. Records of only two species of fresh-water fishes, the four-eye or "quatro-ojo" (*Anableps dovii*) and the top minnow or "chimbola" (*Mollienesia sphenops*, recorded as *Pœcilia salvatoris*) were found. Only a small amount of collecting likewise appears to have been done on the Pacific slope of Guatemala, Honduras, and Nicaragua. It is therefore not surprising that several of the species taken apparently are new. The Pacific slope in El Salvador, as in most of Central America, is narrow and the rivers are short. A large number of species, therefore, is not to be expected. Six marine species have been included with the fresh-water fishes because they appear to be regular visitors. One species of marine catfish, locally known as the "bagre" (*Galeichthys guatemalensis*), is one of the common food fishes found in nearly all the fresh waters, except in the lakes having no outlet. This fish, although to the writer's knowledge not previously recorded from fresh water, has become so much fresh water in its habits in El Salvador that one is led to believe it may be able to maintain itself there. It is understood that this fish, in order to reach Lake Olomega from the sea, would have to scale falls of considerable size situated in the Rio San Miguel. None of the other marine species, such as *Mugil cephalus*, *Centropomus nigrescens*, *C. robalito*, and *C. pectinatus*, which ascend the Rio Lempa far above salt water, appear to be able to ascend beyond the falls, as none was taken by us in the Rio San Miguel above the falls or in Lake Olomega.

The accompanying table shows where the different species of fresh-water fishes were taken in El Salvador, whether their range extends north or south of this country, or both, and whether they are common to both the Atlantic and Pacific drainages or only to the Pacific. It will be seen that most of the fresh-water species inhabit both lakes and streams. The table also shows that several species reach their southernmost range of distribution, so far as known to date, in El Salvador, while every species known from more southern countries also ranges northward of El Salvador.

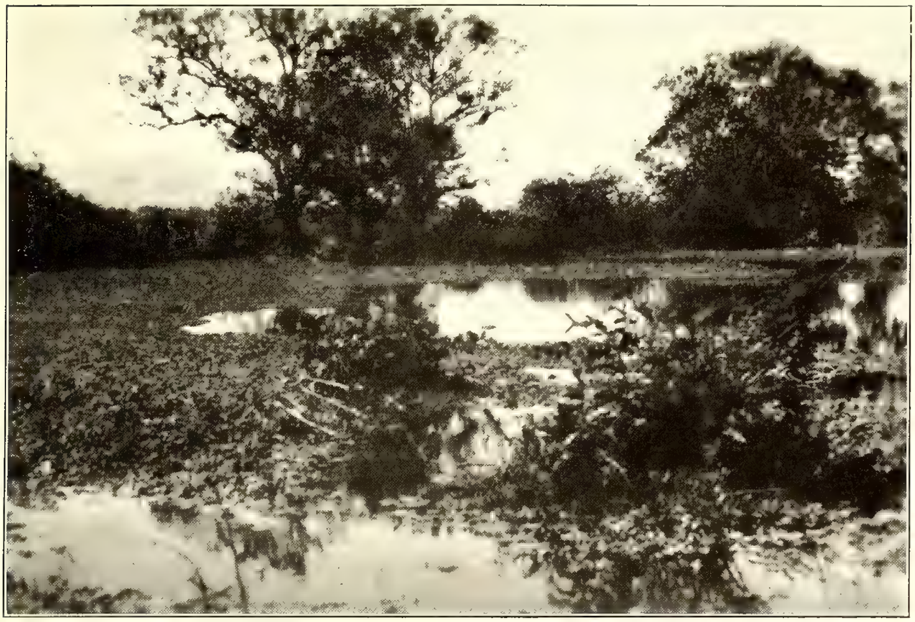

Fig. 5.—Lake Zapotitan. Nearly the entire lake is overgrown with dense vegetation

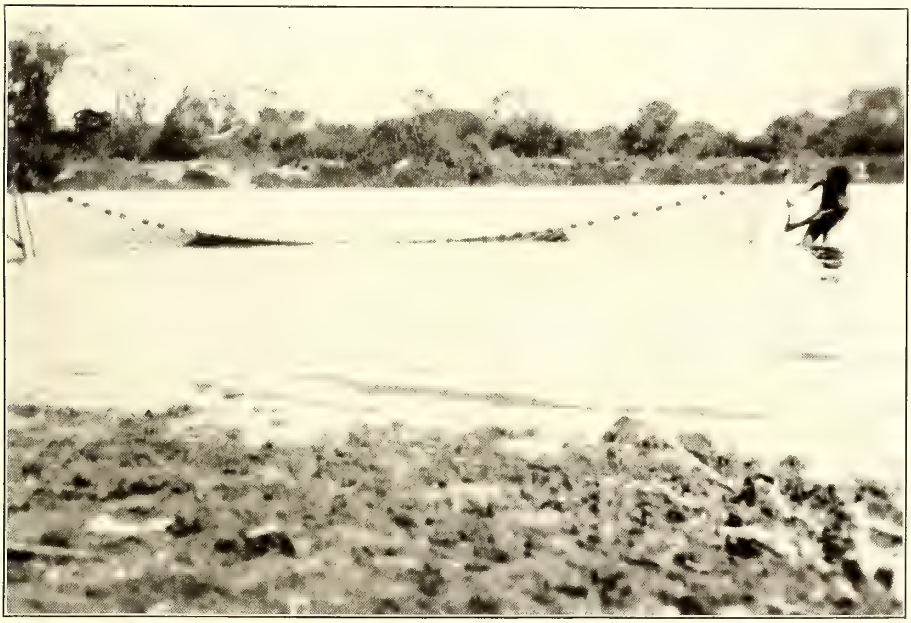

Fig. 6.—Collecting fish in El Salvador

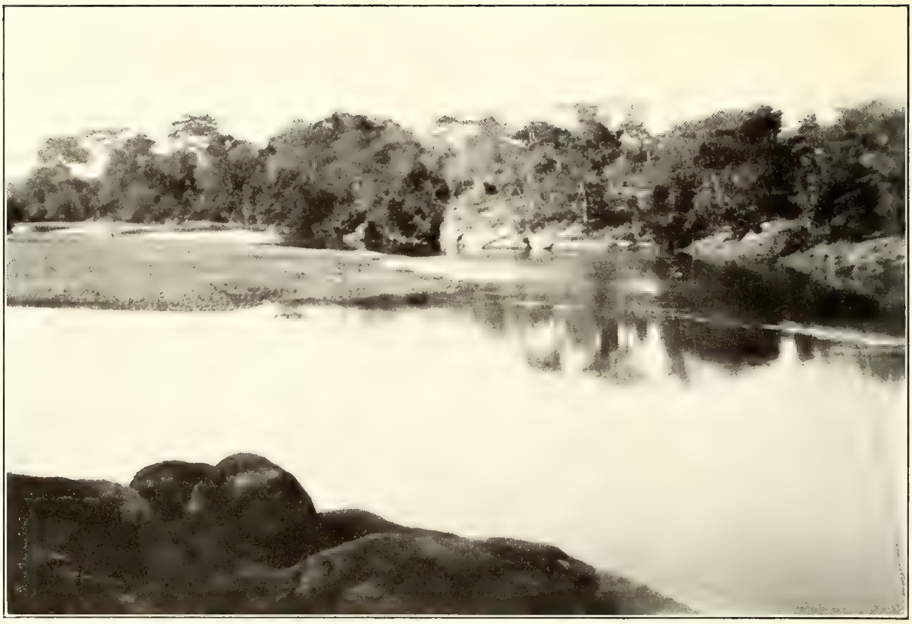

FIG. 7.—Rio San Miguel at San Miguel, during the dry season

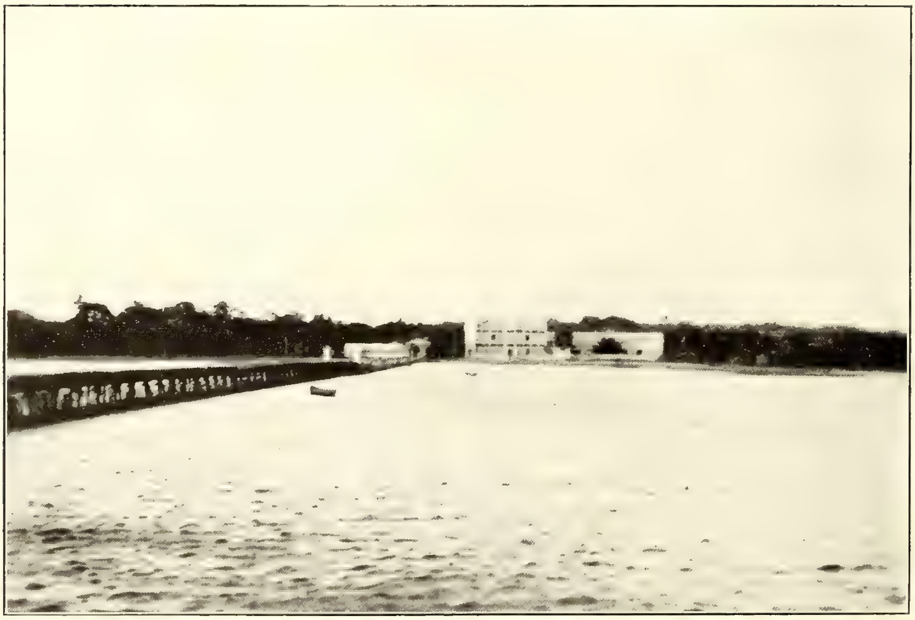

FIG. 8.—Harbor of El Triunfo. A smoking volcano, the San Miguel, is in the background

Table 1.—*Localities in which collections were made in El Salvador and the species taken in each*

[The range of the species, as to whether extending north or south of El Salvador, or both, and also whether extending into both the Atlantic and Pacific drainages or the Pacific only, is indicated]

Species	Lakes									Ponds at El Angel	Rio del Desague near Lake Guija	Tributaries of the Rio de Paz		Rio Sucio at Sitio del Niño, tributary of the Rio Lempa	Small streams at San Salvador	Rio Lempa at Suchitoto	Rio Lempa at San Marcos	Rio San Miguel at San Miguel	Salt and brackish water		Range				
	Guija	Metapan	Ahuachapan	Chalchuapa	Coatepeque	Chanmico	Zapotitan	Ilopango	Olomega			Rio Molino at Ahuachapan	Rio Pampe at Chalchuapa						Triunfo	Cutuco	North	South	El Salvador only	Pacific slope only	Atlantic and Pacific slopes
1. Astyanax fasciatus æнus	×	×					×		×				×	×		×	×				×	×			×
2. Rœboides salvadoris sp. nov	×	×												×		×					×?				
3. Galeichthys guatemalensis	×	×							×							×	×				×	×		×	
4. Arius taylori sp. nov																	×						×		
5. Rhamdia guatemalensis	×	×							×		×			×		×					×				×
6. Profundulus punctatus												×									×			×	
7. Mollienesia sphenops	×	×	×	×	×	×	×	×	×	×	×		×	×	×	×	×	×			×	×			×
8. Priapichthys letonai sp. nov	×	×					×		×		×			×	×	×		×					×		
9. P. fosteri sp. nov																×	×		×				×		
10. Anableps dovii	×								×		×			×		×	×	×		×	×			×	
11. Thyrina guija sp. nov	×										×					×	×						×		
12. Mugil cephalus																×					×	×			×
13. Agonostomus monticola											×						×				×	×			×
14. Centropomus nigrescens																	×				×	×		×	
15. C. robalito																	×		×		×	×		×	
16. C. pectinatus																	×		×		×	×			×
17. Cichlasoma nigrofasciatum	×	×		×	×	×	×	×		×			×	×		×		×			×			×	
18. C. macrocanthus			×																		×			×	
19. C. meeki sp. nov	×	×		×					×					×		×	×	×					×		
20. C. trimaculatum	×	×						×	×							×	×	×			×			×	
21. C. motaguense	×		×		×	×				×											×				×
22. Gobiomorus maculatus																×	×				×	×		×	

ACKNOWLEDGMENTS

The writer wishes gratefully to acknowledge the financial as well as other help given by the officers of the Salvadorian Government. Thanks particularly are due to Señor Dr. Don Marcos A. Letona, Subsecretario de Fomento y Agricultura; Señor Hector David Castro, chargé d'affaires of the Legation of El Salvador, Washington, D. C.; Mr. Frederic W. Taylor, Director General de Agricultura; Senor José Antonio Sasso, chief clerk de Fomento y Agricultura; Seth H. Dyer; and Señor Carlos A. Siri, who served as secretary and interpreter throughout the expedition. The writer also wishes to acknowledge the many courtesies and the help given by Messrs. W. E. Mullins and J. H. Clegg, officers of the International Railway Co. of Central America. Messrs. Max Kohlmeyer and John Bocker, business men of San Miguel, also rendered helpful assistance. To my colleague, Fred J. Foster, superintendent of the United States fisheries station, Neosho, Mo., who was with the author throughout the expedition, much credit is due for the success of the work and the completeness of the collection upon which the present report is based. Irving L. Towers, scientific assistant, Bureau of Fisheries, deserves credit for much valuable assistance rendered in the preparation of the report. The illustrations of fishes are from photographs made by Herbert F. Prytherch, scientific assistant, Bureau of Fisheries, and retouched by an artist. The plants mentioned in the text were identified by Paul C. Stanley, of the National Museum.

EXPLANATORY NOTES

The usual abbreviations used in systematic ichthyology by most recent authors has been followed. For example, the expression "head 3.3 to 4.1; depth 4.3 to 6.2" signifies that the length of the head, measured from the tip of the upper jaw to the bony margin of the opercle (unless otherwise specified), is contained 3.3 to 4.1 in the "standard length"—that is, in the distance from the end of the snout to the base of the caudal fin—and the greatest depth of the body is contained 4.3 to 6.2 times in the standard length. In giving the number of spines and rays contained in a fin the spines are designated by Roman numerals and the soft rays by Arabic numerals. For example, "D. VII–I, 14; A. III, 8" signifies that the dorsal fins are separate and that the first consists of 7 spines and the second of 1 spine and 14 soft rays, and that the anal is continuous, being composed of 3 spines and 8 soft rays. If, in the case of the dorsal fin, the spines and rays had all been connected so as to form a single continuous fin, the result would have been written thus: D. VIII, 14. The number of scales given in the description, unless otherwise stated, is the number of oblique rows, running upward and backward, that occur just above the lateral line. This series is counted from the upper anterior angle of the gill opening to the last large scale on the base of the caudal.

In the arrangement of the families, Jordan's "A Classification of Fishes" (Stan. Univ. Pub., Univ. Ser. III, No. 2, 1923, pp. 79–243) was followed.

In order to render the catalogue more useful for ready identification keys to the families, genera, and species have been introduced. Since the species occurring in the waters of El Salvador are few, the keys are all short and no difficulty in using them should be experienced. No attempt has been made in the keys to show the natural relationship of the various groups. In using the keys first determine to which of the major groups the species in hand belongs, then take up the regular order of letters under that group. If the characters of the specimen do not agree with those under the single letter, look under the double letter, ignoring all intervening matter.

Following is a list of the species which appear as new in the present paper:

	Page		Page
Rœboides salvadoris	246	Priapichthys fosteri	260
Arius taylori	250	Thyrina guija	264
Priapichthys letonai	258	Cichlasoma meeki	275

Part I.—DESCRIPTIVE CATALOGUE OF THE FISHES OCCURRING IN THE FRESH WATERS OF EL SALVADOR

All of the fishes of the fresh waters of El Salvador belong to the class *Pisces* (fishes) and to the superorder *Teleostei* (the bony fishes), which possess a bony skeleton, a well-developed skull, a single gill opening on each side, at least two nostrils that are not median, and well-developed fins.

KEY TO THE FAMILIES OF FISHES OCCURRING IN THE FRESH WATERS OF EL SALVADOR [2]

a. Scales wanting, body mostly covered with smooth skin; mouth and nostrils with several pairs of barbels or whiskers.
  b. Nostrils close together, neither with a barbel; palatine teeth present------*Ariidæ,* p. 248.
  bb. Nostrils remote from each other, the posterior one without a barbel; teeth wanting on palatines------*Pimelodidæ,* p. 251.
aa. Body scaled; no barbels about the nostrils or mouth.
  c. Fins without spines.
    d. Adipose fin present; head naked; lateral line present------*Characinidæ,* p. 244.
    dd. Adipose fin wanting; head partly scaled; lateral line wanting.
      e. Eye divided into an upper and lower portion by a dark-colored membrane in the cornea; anal fin in the male modified into a thick scaly conical copulatory organ with an orifice at its extremity------*Anablepidæ,* p. 261.
      ee. Eye normal, not as above; anal fin in the male normal or produced, but not forming a conical organ with an orifice.
        f. Anal fin modified, the anterior rays more or less produced, forming an intromittent organ, but not enveloped in skin and not hollow as in *Anableps*--*Pœciliidæ,* p. 254.
        ff. Anal fin normal in both sexes------*Cyprinodontidæ,* p. 253.
  cc. Fins with spines.
    g. Body elongate, not very deep; dorsal fins 2, separate.
      h. Ventral fins abdominal; lateral line usually absent, never complete.
        i. First dorsal with 3 to 9 flexible spines; anal fin with a single weak spine------*Atherinidæ,* p. 263.
        ii. First dorsal with 4 rather strong stiff spines; anal with 3 strong spines (sometimes 2 in very young)------*Mugilidæ,* p. 265.
      hh. Ventral fins thoracic.
        j. Lateral line complete, continued to end of caudal fin; anal with 3 spines, the second very strong; caudal fin forked------*Centropomidæ,* p. 268.
        jj. Lateral line wanting; anal fin with a single weak spine; caudal fin rounded------*Eleotridæ,* p. 281.
    gg. Body deep, compressed; lateral line interrupted under base of dorsal, reappearing lower down on side; dorsal fin single, composed of spines and rays------*Cichlidæ,* p. 272.

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[2] This key is intended to identify only the species of these families which occur in El Salvador, as some of the characters mentioned are not true of the families as a whole.

Class PISCES

Order HETEROGNATHI

Family I. CHARACINIDÆ

The Characins

Body variously shaped, usually more or less compressed; upper jaw mesially formed by premaxillaries, laterally by maxillaries; teeth various; scales present, usually cycloid, wanting on head; dorsal fin small, without spines; adipose fin usually present.

KEY TO GENERA

a. Teeth in upper jaw in 2 series, none of them directed forward; anal fin of moderate length; usually composed of less than 30 rays ------------------------------ *Astyanax*, p. 244.

aa. Teeth in upper jaw more or less definitely in 3 series, the outer series composed of strong teeth situated on outer margin of jaw and directed forward; anal fin very long, usually composed of 45 or more rays -------------------------------------- *Rœboides*, p. 246.

1. Genus ASTYANAX Baird and Girard

Astyanax Baird and Girard, Proc., Ac. Nat. Sci., Phila., VII 1854 (1856), 26 (type *Astyanax argentatus* Baird and Girard).

Body more or less elongate, compressed, the depth usually more than 2 in length; second suborbital narrow, leaving a naked triangular area below suture between first and second suborbitals; premaxillaries with 2 series of teeth, the first with several teeth on each side, the second equal or graduated, usually 10, sometimes 8 in number; lower jaw with strong teeth anteriorly, usually abruptly smaller, conical ones on sides; maxillary with a few or no teeth; gill rakers setiform; lateral line complete; no predorsal spine; adipose fin present; anal fin of moderate length, usually of fewer than 30 rays; caudal fin naked.

1. Astyanax fasciatus æneus (Günther)

PLATEADA; SARDINA

Tetragonopterus æneus Günther, Proc., Zool. Soc. London, 1860, 319 (Oxaca, Mexico).

Astyanax fasciatus æneus Eigenmann, Memoir., Mus. Comp. Zoöl., XLIII, Part 3, 1921, 306. (A complete synonomy is given here by Eigenmann, to which the reader is referred for further references.)

Head 3.5 to 5.13; depth 2.3 to 4.05; D. 11; A. 25 to 31; scales 33 to 38.

Body compressed, variable in depth and thickness; profile almost straight over the head, convex from nape to dorsal; caudal peduncle strongly compressed, broadly rounded underneath, its depth 1.85 to 2.55 in head; head small; snout blunt, 3.25 to 4.1 in head; eye 2.75 to 4.3; interorbital 2.45 to 3.1; mouth moderate, terminal; maxillary reaching to or slightly past anterior margin of eye, 2.5 to 3 in head; teeth strong, mostly tri- to multicuspid, in 2 series on the premaxillaries, the outer series with 8, the inner with 10 teeth, 2 teeth on each maxillary, 8 or 9 large teeth anteriorly on the lower jaw and abruptly smaller ones laterally; gill rakers short, 11 to 14 on the lower limb of the first arch; lateral line complete, slightly decurved; scales rather large, 10 to 12 rows crossing the back in front of dorsal, 10 or 11 between the dorsal and adipose, 6 or 7 from origin of dorsal to lateral line; dorsal elevated anteriorly, its origin equidistant from tip of snout and base of caudal or more usually a little nearer the former; adipose over the posterior rays of the anal; caudal fin broadly forked; anal fin rather long, its origin at or slightly behind vertical from end of dorsal base, usually about equidistant from margin of opercle and base of caudal; ventral fins moderate, inserted a little in advance of dorsal; pectorals short, 1.2 to 1.35 in head.

Color in life silvery with bluish green above; sides with an ill-defined bright silvery streak, most evident posteriorly; a dark shoulder spot, and frequently an indication of a second black spot behind it; dorsal olivaceous; caudal greenish, with an elongate black spot at its base extending to the end of the median rays; anal pink to deep red; ventrals usually more or less reddish; pectorals yellowish to red; upper part of iris red to reddish yellow.

Many specimens of this species, ranging in length from 20 to 135 millimeters, were preserved. This fish is very common in some localities but absent in others. It is especially abundant in Lake Olomega, where large quantities are taken and used for food. It was not taken in Lakes Ahuachapan, Chalchuapa, Coatepeque, Chanmico, and Ilopango. Especially large and fine specimens were taken in the Rio Pampe, a tributary of the Rio de Paz, near Chalchuapa. The individuals taken here are somewhat more slender, and they have a less distinct lateral band than the fish taken elsewhere. This fish inhabits the deeper parts of rocky and swiftly-flowing streams as well as quiet and shallow water.

The alimentary canal in this species is shorter than the body, and the peritoneum is black. The food found in 5 stomachs examined consisted of water fleas, copepods, water beetles, and fragments of fish. The sexual organs in the specimens dissected were collapsed, showing that spawning was not taking place during the period (January and February) when the specimens were collected.

A. fasciatus is an extremely variable species and many forms have been described. The specimens from El Salvador appear to be nearest the form which Eigenmann, in his monumental work, "The American Characidæ," has designated as *A. fasciatus æneus*. It was pointed out in the preceding paragraph, however, that the specimens from the Rio de Paz basin differ somewhat from those taken elsewhere in El Salvador. Eigenmann, in speaking of the many variations, says: "Whether we call these forms species, varieties, or do not recognize them as worthy of name, the fact remains that different rivers are inhabited by individuals that in the aggregate differ from the individuals of another river, * * * that we have here a series of species in the making as the result of segregation." It would appear that at last two species are "in the making" in El Salvador.

This form, according to Eigenmann, ranges from Mexico to Panama. The specimens from El Salvador are from the Rio Pampe at Chalchuapa, Lake Guija, Lake Metapan, Lake Zapotitan, Rio Sucio at Sitio del Niño, Rio Lempa at Suchitoto and San Marcos, Rio San Miguel at San Miguel, and Lake Olomega.

2. Genus RŒBOIDES Günther

Rœboides Günther, Cat. Fish., Brit. Mus., V, 1864, 345 (type *Anacyrtus guatemalensis* Günther).

Body compressed; dorsal profile concave at nape in adult; teeth mostly pointed, in 3 more or less definite series in upper jaw, the outer ones of both jaws directed forward; shoulder girdle with a large spine; lateral line straight, complete; anal fin very long, with 45 or more rays; adipose fin well developed.

2. **Rœboides salvadoris** sp. nov.

Plateado; Sardina; Alma Seca; Ulumina

Type no. 87215, U.S.N.M. Length, 91 mm. Rio Sucio, Sitio del Niño.

Head 3.35 to 4.25; depth 2.55 to 3.4; D. 11; A. 46 to 50; scales 15 or 16—72 to 82; pores in lateral line variable, 53 to 73.

Body strongly compressed; the dorsal region elevated; profile deeply concave at occiput in the adult, not at all concave in young of 40 millimeters and less in length; head comparatively small; snout blunt, 3.25 to 3.9 in head; eye small, 3.2 to 3.8 in head or 11.5 to 15 in body; interorbital 3.2 to 3.8 in head; mouth large; maxillary notably broader than preorbital, reaching anterior margin of pupil to middle of eye, 2.1 to 2.5 in head; teeth moderate, 4 with broad conical bases, directed forward on margin of snout, 2 to 4 similar ones at sides on the maxillary and 2 on the margin of mandible; outer margin of maxillary with pointed teeth; premaxillary with irregular teeth, irregularly placed, some of the inner ones with small basal cusps; mandibular teeth all pointed, the anterior ones the largest, none of them definitely tricuspid; gill rankers short, 8 or 9 on the lower limb of the first arch; shoulder girdle with a spine, pointed both anteriorly and posteriorly, reaching nearly to base of pectoral; lateral line complete, nearly straight; scales very small; dorsal fin moderately elevated anteriorly, its origin equidistant from tip of snout and base of caudal or more usually a little nearer the former; the elevated portion measured from the origin of the fin to the tip of the longest rays 3.45 to 4.3 in body; adipose fin moderate, situated over the posterior part of anal; caudal fin deeply forked; anal fin very long, its origin equidistant from tip of snout and base of last anal ray or more usually a little nearer the former; ventral fins rather short, reaching opposite the fourth to the sixth anal ray, 5.25 to 6.4 in body; pectorals moderate, failing to reach the origin of anal, 1.3 to 1.45 in head or 4.6 to 5.7 in body; vertebræ 12+22.

Color in life silvery, slightly olivaceous on back; sides with a silvery band, most definite posteriorly; base of caudal with dark punctulations on a silvery background, forming a dark caudal spot; a smaller dark spot just above the lateral line and posterior to the vertical from base of ventrals, deeper than long, and variable in intensity, but not entirely wanting on any of the specimens at hand; upper parts of head dark; fins all greenish.

Many specimens of this species, ranging from 35 to 105 millimeters in length, were preserved. This fish is not universally distributed in the waters of El Salvador. It is abundant among vegetation in Lake Guija, apparently rather rare in Lake

Metapan, and common in the Rio Sucio at Sitio del Niño and in the Rio Lempa at Suchitoto. Elsewhere it was not seen.

The sexual organs in the fishes examined were in a collapsed condition, showing that spawning was not taking place during the period (January and February) when the specimens were collected. The air bladder is large and the alimentary canal is short. The contents of 4 stomachs examined consisted of fragments of insects and the scales of fish, which apparently remained after the rest of the fish had been digested.

The specimens from El Salvador evidently represent a species distinct from those of Panama. Material from other Central American countries is not available to the author for comparison. Günther, the discoverer of *R. guatemalensis,* considered his specimens from the Pacific slope of Guatemala identical with others obtained in the Rio Chagres in Panama. Authors, generally, had recognized but a single species from Central America. Meek and Hildebrand (Pub., Field Mus. Nat. Hist., Zoöl. Ser., X, 1916, pp. 291–3), however, found that the specimens from the Pacific slope of Panama were different from those of the Atlantic slope, and they described the former as new, giving it the name *occidentalis.* The Atlantic specimens were considered as *R. guatemalensis* of Günther, which is probably correct, for Günther, when describing the species, had some young from the Pacific slope of Guatemala and adult specimens from the Rio Chagres, Panama. Günther's description appears to have been based upon the adult fish, for he says: "Back elevated, the upper profile of the head and nape forming an S-shaped curve." This appears never to be true of the young of the genus. The Atlantic representatives from Panama, therefore, may for the present, at least, be considered the true *guatemalensis*, regardless of whether or not they are identical with specimens from Guatemala, which seems highly doubtful.

The El Salvador specimens differ from both the Panama species with which a direct comparison of specimens has been made, in having a smaller eye, shorter fins, in color markings, and in other minor respects. The number of scales in a lateral series appears to be nearly identical in the present species and in *R. occidentalis.* The number of gill rakers, however, is more nearly that of *R. guatemalensis.* In the position of the dorsal and anal the El Salvador specimens appear to be intermediate.

The diameter of the eye in the body in 12 specimens of the present species varying from 60 to 82 millimeters in standard length, ranges from 11.8 to 13.5, the average being 13.35. In an identical series of *guatemalensis* the range is from 9.4 to 13.1, average 11.63; in *occidentalis* the range is 10.03 to 13.3 and the average 11.64. The length of the fins in the body for 20 specimens from El Salvador, ranging in standard length from 28 to 86 millimeters, are as follows: Pectoral, 4.5 to 5.8, average 5.32; ventral 5.1 to 6.43, average 5.81; dorsal 3.44 to 4.3, average 3.94. The results for a similar series of *R. guatemalensis* are as follows: Pectoral 4.55 to 5.55, average 4.92; ventral 4.6 to 5.8, average 5.21; dorsal 3.2 to 3.66, average 3.51. For *occidentalis,* also using a like series of specimens, the following results were obtained: Pectoral 4.2 to 4.94, average 4.63; ventral 4.03 to 5.05, average 4.68; dorsal 3.1 to 3.5, average 3.32. The Salvador specimens, therefore, represent what Dr. C. H. Eigenmann, in several of his recent works, has called a "statistical species."

In color the El Salvador specimens differ from *R. guatemalensis* in having no black in the lateral band, and in having a more or less distinct dark spot on the sides, which, however, is much smaller than the one in *occidentalis.*

Fowler (Proc., Ac. Nat. Sci., Phila., LXXV, 1923 (1924), p. 25) recently described *Rœboides bouchellei* from Great Falls, Pis Pis River, of the Atlantic slope of Nicaragua. According to the description, this species would appear to be close to the present one. It appears to differ as follows, however: (1) In the shorter maxillary, which is described as reaching only to the eye, while in the Salvador fish it reaches well beyond this point. (2) The preorbital, in comparison with the maxillary, is broader, being described as equal in width to the maxillary. In the specimens at hand it is always notably narrower. (3) Fowler counts 52 rays in the anal fin of his type. The largest number found in 25 specimens from El Salvador is 50. It is possible, therefore, that at least the average number for Nicaraguan specimens is higher. (4) The pectorals in *R. bouchellei* are described as reaching the anal and to be contained 1.66 in head. In the specimens at hand they do not reach the origin of the anal, yet they are contained only 1.3 to 1.45 in head. (5) The dark spot on the side situated just above the lateral line is described for *R. bouchellei* as being "midway in the predorsal length." In the El Salvador specimens it is only about an eye's diameter in advance of origin of dorsal. (6) The bright silvery lateral band, very evident in all alcoholic specimens from El Salvador, is not mentioned for *R. bouchellei.*

The specimens from El Salvador were collected in lakes Guija, Metapan, and in the Rio Sucio at Sitio del Niño, and in the Rio Lempa at Suchitoto.

Order NEMATOGNATHI

Family II. ARIIDÆ

The Sea Catfishes

Body elongate; head broad, depressed; nostrils close together, neither with a barbel, the posterior with a valve; palatine teeth present; skin naked; dorsal fin present, short, situated above or in front of ventrals; adipose fin present; caudal fin lunate or forked.

KEY TO THE GENERA

a. Teeth all pointed; present on the jaws, vomer, and palatines----------- *Galeichthys,* p. 248.
aa. Teeth wanting on the vomer; those on the palatines broad and blunt-------- *Arius,* p. 250.

3. Genus GALEICHTHYS Cuvier and Valenciennes

Galeichthys Cuvier and Valenciennes, Hist. Nat. Poiss., XV, 1840, 28, (type *Galeichthys feliceps* Cuvier and Valenciennes).

This genus may be recognized by the presence of pointed teeth on the jaws, vomer, and palatines. The palatine teeth are in small or moderate patches and do not have a backward extension. A single species belonging to this saltwater genus is present in most fresh waters of El Salvador.

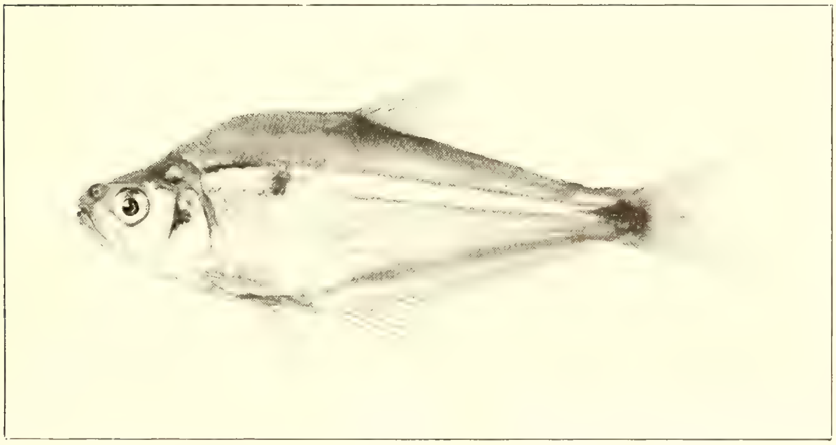

Fig. 9.—*Roeboides salvadoris* sp. nov. From the type. Length, 91 millimeters

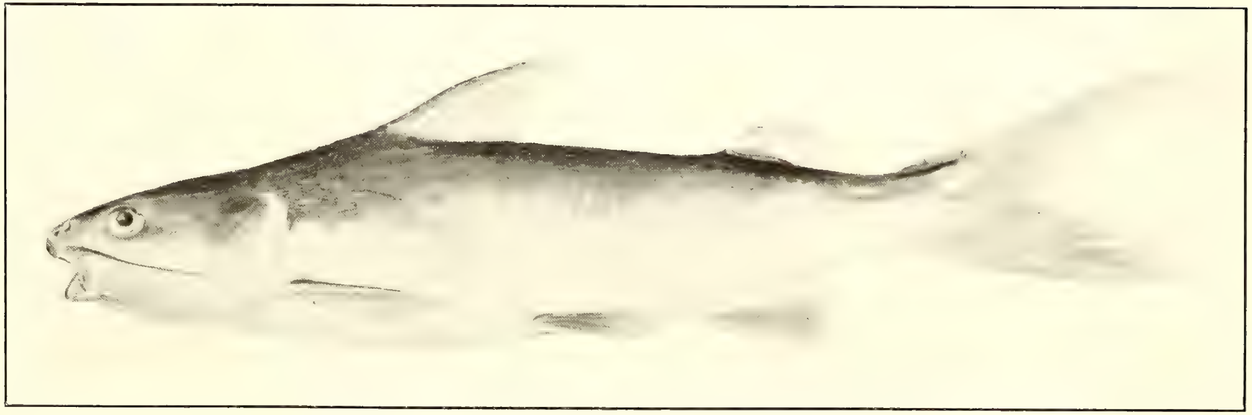

Fig. 10.—*Arius taylori* sp. nov. From the type. Length, 360 millimeters

3. **Galeichthys guatemalensis** (Günther)

BAGRE

Arius guatemalensis Günther, Cat. Fish. Brit. Mus., V, 1864, 145 (Guatemala).
Tachisurus guatemalensis Eigenmann and Eigenmann, Proc., Cal. Ac. Sci., 2 ser., I, 1888, 43, and Occ. Pap., Cal. Ac. Sci., 1890, 81.
Galeichthys guatemalensis Jordan and Evermann, Bull., U. S. Nat. Mus., XLVII, 1898, 2778; Regan, Biol. Cent. Amer., Pisces, 1907, 123.

Head 3.3 to 4.1; depth 4.3 to 6.2; D. I, 7; A. 17 to 19.

Body about as broad as deep at origin of dorsal, moderately compressed posteriorly; caudal peduncle rather long, its depth 3.65 to 4.8 in head; head broad, depressed, flat above; snout very broad, its length 2.75 to 3.7 in head; eye 4.5 to 8; interorbital 1.8 to 2.3; mouth very broad; upper jaw strongly projecting; teeth pointed, the band in upper jaw continuous, the one in lower jaw separated at symphysis, extending laterally well past the angle of mouth and ending in a sharp point; vomerine patches well separated from each other and from the larger palatine patch by a line and slight constriction; maxillary barbel scarcely reaching margin of opercle in adult, past base of pectoral in small specimens (150 millimeters and less in length); gill rakers, 11; distance from snout to dorsal 2.4 to 3 in length; upper surface of head granular in adult, almost smooth in young, occipital process a little longer than broad; fontanel scarcely produced in a groove, appearing as an elongate pit slightly behind a straight line drawn between the posterior margin of the eyes; dorsal fin small, its origin usually about equidistant from tip of snout and origin of adipose, the spine about three-fourths the length of the longest rays, 1.7 to 2.1 in head; adipose fin small, its base 3.1 to 4 in head; caudal fin deeply forked, the upper lobe the longer, pointed; anal fin moderate, its origin under or a little posterior to that of the adipose, its base 1.75 to 2.8 in head; ventral fins shorter than pectoral, thickened, and somewhat longer in the female than in the male, usually inserted a little nearer end of anal base than base of pectoral spine; pectoral spine with barbs on the inner edge, 1.6 to 1.8 in head.

Color, bluish dusky above; sides silvery; pale underneath; vertical fins all dusky, the anal sometimes partly pale; paired fins black on inner sides.

Thirteen specimens, ranging from 88 to 395 millimeters in length, were preserved. The largest individual taken measured 560 millimeters in length, which, according to local fishermen, is about the maximum size attained. Measurements and proportions were obtained from this fish and are included in the description. This fish, which is known as "bagre" throughout the Republic, although belonging to a salt-water genus of catfishes, appears to have become fresh water in its habits, at least in El Salvador, where it is one of the important commercial species caught in the rivers and in some of the lakes. It was not taken in any of the lakes having no outlet (unless the statement that Lake Metapan has an underground connection with Lake Guija should prove to be erroneous), and consequently it does not appear to have become definitely landlocked, the distribution apparently being such that it can retreat to the sea at will. Falls of considerable size are present in the Rio San Miguel, which receives the water from Lake Olomega and carries it to the sea, and no other marine species were seen in the lake nor in that river above the falls. It may be, however, that this catfish is able to ascend the falls and that it reaches the lake from the sea. The species is said to be nocturnal in its habits, hiding among rocks or elsewhere during the day and coming out at night to feed. It is more abundant in Lake Olomega than in any other locality where collections were made. It does not appear to be esteemed there as a food fish, however, for the native fishermen did not care to save the fish not desired for specimens. Large numbers, however, are sun-dried and shipped. Several bundles, weighing 100 pounds or more, inclosed in nets, were seen at the local railway station.

Three large females taken in the Rio Lempa at Suchitoto on February 5 were examined and found to contain eggs provided with large, red, blood vessels and measuring about 10 millimeters in diameter. The eggs were still attached to the ovary by prominent stalks, and since it is known that marine catfishes produce very large eggs it is improbable that the spawning period was immediately at hand, although it might be expected to occur within a month or so. Two large specimens examined had fed on crabs and crawfish, while two smaller ones had eaten fish, snails, insects, and insect larvæ.

This species ranges from Mazatlan, Mexico, to Panama. The specimens at hand were taken in Lake Guija, Lake Metapan, Rio Lempa at Suchitoto and San Marcos, and in Lake Olomega.

4. Genus ARIUS Cuvier and Valenciennes

Arius Cuvier and Valenciennes, Hist. Nat. Poiss., XV, 1840, 53, (type *Pimelodus arius* Hamilton).

This genus of catfishes is characterized by the absence of teeth on the vomer and by the broad blunt teeth on the palatines, which are in small or moderate-sized patches and without backward projections. A single apparently undescribed species of this salt-water genus was taken in strictly fresh water. It is therefore included here with the fresh-water species.

4. **Arius taylori** sp. nov.

BAGRE

Type No. 87224, U.S.N.M.; length 360 mm.; Rio Lempa, San Marcos.

Head 3.8; depth 4.6; D. I, 7; A. 23.

Body moderately elongate, somewhat deeper than broad at origin of dorsal, posteriorly compressed; caudal peduncle rather slender, its depth 3.25 in head; head not very broad, flat above; snout moderate, 3.25 in head; eye large, lateral, 5.5; interorbital 2.25; mouth not excessively broad, its width scarcely equal to interorbital space; teeth in the upper jaw villiform, divided by a narrow line, not pointed posteriorly and not reaching angle of mouth, each half about twice as long as broad; teeth on lower jaw all pointed except the posterior one at middle of jaw, these blunt like the palatine teeth, the band well separated at symphysis, tapering and pointed posteriorly, and extending well past angle of mouth, its greatest width less than one-third the length of each patch; vomerine teeth wanting; palatine teeth blunt, in small patches, placed far apart, the distance between them about equal to half the length of the band on upper jaw; maxillary barbel reaching to margin of opercle; gill rakers 11; distance from snout to dorsal 2.7 in length; top of head only feebly granular; occipital process scarcely as broad as long, scarcely keeled; an elongate pit on snout and a fontanel groove reaching from posterior part of interorbital nearly to occipital process; dorsal fin rather small, its origin about equidistant from tip of snout and origin of adipose, the spine 1.6 in head; adipose fin rather large, its base 3.1 in head; caudal fin long, deeply forked, both lobes pointed, the posterior margin definitely V shaped, the upper lobe the longest, a little longer than head; anal fin moderate, its origin about an eye's diameter in advance of the adipose, the length of its base 1.55 in head; ventral fins rather short, failing to reach the origin of anal, inserted about equidistant from base of pectoral spine and middle of anal base; pectoral spine short, 1.6 in head.

Color in alcohol dark brownish above, sides silvery, pale underneath, the fins all slightly dusky.

A single specimen, 360 millimeters long, was preserved. The species was not distinguished from *G. guatemalensis* in the field, therefore others may have been captured but not preserved.

The species appears to be related to *A. furthii*, known from Panama. The El Salvador specimen, however, has a much longer and more deeply forked caudal fin, the lobes being pointed and equal to or longer than the head, and the outer margin is definitely V shaped. In *A. furthii* the lobes of the caudal are not pointed and are notably shorter than the head, and the outer margin of the fin is broadly V shaped. The eye in the El Salvador fish is larger, the fins are longer, the palatine patches of teeth are much smaller and farther apart, and the band of teeth on the lower jaw is narrower.

The specimen in hand was taken in strictly fresh water at San Marcos, where the bridge of the International Railroad of Central America crosses the Rio Lempa, about 30 kilometers from the sea. The species is named for Frederic W. Taylor, director general of agriculture for the Government of El Salvador, under whose immediate direction the investigation was made.

Family III. PIMELODIDÆ

Body elongate, compressed posteriorly; head broad; mouth terminal or slightly inferior; barbels, 6; nostrils remote from each other, the posterior one without a barbel; teeth wanting on palatines; adipose fin present, usually long.

5. Genus RHAMDIA Bleeker

Pteronotus Swainson, Nat. Hist. Class. Fish., II, 1839, 309 (type *Heterobranchus sextentaculatus* Agassiz).

Rhamdia Bleeker, Verhand. Natuurk. Vereen. Nederl. Indie, IV, 1859, 197 (sp.); Bleeker, Nederl. Tijdschr. Dierk., I, 1863, 101 (type *Pimelodus quelen* Quoy and Gaimard).

Pimelenotus Gill, Ann. Lyc. Nat. Hist., N. Y., VI, 1858, 391 (type *Pimelenotus vilsoni* Gill).

Body elongate; jaws with villiform teeth; no teeth on vomer or palatines; nostrils remote from each other; barbels, 6; no nasal barbel; occipital process small or wanting, never reaching dorsal plate; eye with free orbital margin; dorsal fin with 1 slender spine and 5 to 8 branched rays; adipose fin long, adnate to the back. A single species of this genus was taken in El Salvador.

5. **Rhamdia guatemalensis** (Günther)

FILIN

Pimelodus guatemalensis Günther, Cat. Fish. Brit. Mus., V, 1864, 122 ("Huamuchal," Pacific slope of Guatemala).
Rhamdia wagneri Jordan and Evermann, Bull., U. S. Nat. Mus., XLVII, 1896, 152; Regan, Biol. Cent. Amer, Pisces, 1907, 132.

Head 3.65 to 4.25; depth 4.4 to 6.25; D. I, 6; A. 11 to 13.

Body elongate, compressed posteriorly; caudal peduncle strongly compressed, its depth 2 to 2.45 in head; head depressed, its depth about three-fourths its width; snout broad, its length 2.55 to 2.8 in head; eye 5.3 to 6.2; interorbital 2.95 to 3.6; mouth broad, almost wholly transverse, its width equal to length of snout and half of eye; teeth small, in rather broad villiform bands in each jaw; maxillary barbel variable in length, apparently always reaching past the origin of the adipose and occasionally nearly to the end of this fin; dorsal fin rather small, round, the spine about three-fourths the length of the longest rays, 2.4 to 3.3 in head, origin of fin equidistant from tip of snout and vertical from origin of anal or a little nearer the latter; adipose fin long, its base 2.4 to 2.7 in body; caudal fin deeply forked, the median rays scarcely half the length of the longest; anal fin with convex margin, its origin a little anterior to middle of base of adipose; ventral fins short, inserted at vertical from end of dorsal base; pectorals small, the spine strong, without definite barbs on the inner margin, its length 2.2 to 3 in head.

Color in life plain dark green, usually with a dark lateral band; dorsal, adipose, caudal, and anal dusky; the other fins paler.

This fish is represented by 9 specimens ranging from 90 to 185 millimeters in length. The species does not appear to be abundant enough anywhere to be of much commercial importance. The few individuals that were seen were quite small, none of them exceeding 185 millimeters in length. This catfish inhabits both lakes and streams, and it is said to be nocturnal in its habits, hiding during the day and coming out to feed principally at night. It is taken chiefly with hook and line.

The contents of the stomachs examined consisted of the remains of fish, fragments of insects, and strands of algæ. The ovary of a fish 185 millimeters long, taken in Lake Guija on January 25, was fairly well developed. Its length was 48 millimeters, and it contained several thousand eggs approximately 0.5 millimeters in diameter. It seems probable that this fish would have spawned within about one month.

This catfish is recorded from western Guatemala, and according to Regan it also occurs in southern Mexico and in British Honduras. The El Salvador specimens are from Lake Guija, Rio del Desague, Lake Metapan, Rio Sucio at Sitio del Niño, Rio Lempa at Suchitoto, and Lake Olomega. It was not seen elsewhere.

Order CYPRINODONTES

Family IV. CYPRINODONTIDÆ

The Killifishes

Body elongate, compressed posteriorly; head more or less flattened above; mouth small; premaxillaries strongly protractile; teeth present on both jaws; lateral line wanting; dorsal fin single; anal fin not modified in male; species oviparous.

6. Genus PROFUNDULUS Hubbs

Profundulus Hubbs, Misc. Pub., Mus. Zoöl., Univ. Mich., No. 13, 1924, 12 (type *Fundulus punctatus* Günther).

Body rather robust; head somewhat depressed; dorsal and anal fins relatively long and low and inserted far posteriorly; anal fin lower in the adult male than in the adult female; the oviduct not produced and not extending on the first ray of the anal fin, as in Fundulus. A single species was taken in El Salvador.

6. Profundulus punctatus (Günther)

CHIMBOLA

Fundulus punctatus Günther, Cat. Fish., Brit. Mus., VI, 1866, 320, and Trans., Zoöl. Soc., London, VI, 1868, 482, Pl. LXXXIV, fig. 5 (Chiapas, Guatemala); Regan, Biol. Cent. Amer., Pisces, 1907, 78.

Fundulus guatemalensis Günther, Cat. Fish., Brit. Mus., VI, 1866, 321, and Proc., Zoöl. Soc., London, VI, 1868, 482, Pl. LXXXIV, figs. 3 and 4 (Lakes Duenas and Amatlan, and Rio Guacalate).

Head 3 to 3.7; depth 2.9 to 3.8; D. 12 or 13; A. 13 or 14; scales 31 to 33.

Body rather robust, compressed; caudal peduncle strongly compressed, its depth 1.75 to 2.15 in head; head somewhat depressed; snout broad, 3 to 3.5 in head; interorbital 2 to 2.4; mouth transverse; the lower jaw slightly projecting; teeth in bands, pointed, the outer ones enlarged; scales firm, cycloid, 10 or 11 rows between the dorsal and anal, many of the scales along the upper part of sides with pits; dorsal small, its origin usually about equidistant from the posterior margin of the eye and the end of the caudal; caudal fin broadly rounded; anal fin somewhat longer than the dorsal, its origin a little behind that of the dorsal; ventral fins small, about as long as snout and half the eye, reaching nearly or quite to the vent; pectoral fins broad, 1.45 to 1.75 in head.

Color brownish green above, pale underneath; a dark blotch above and behind base of pectoral; most specimens with a dark lateral band posteriorly, this band wanting in some specimens and broken up into spots in others; occasionally with a series of pale spots above and below the lateral band; a dark vertebral band; the scales on upper part of sides and on base of caudal frequently with dark spots; fins mostly yellowish in life; the dorsal and caudal dusky in spirits, the former with indications of a dark bar at base; the other fins usually all pale, the anal occasionally slightly dusky and with a white margin.

This species is represented by 26 specimens, ranging from 25 to 77 millimeters in length. It was taken only in Rio Molino, a rather small tributary to the Rio de Paz. This stream was visited late on the evening of January 27, and only a small stretch, in the vicinity of Ahuachapan, was seen. That portion was too rocky to permit of the operation of a drag net. Three charges of dynamite produced only the species here described and, according to a native who was questioned, the stream in that vicinity contains no other fish.

One of the large females examined had large roe, the ovary containing 30 eggs measuring 2.25 millimeters in diameter and an equal number approximately half that size. The food in the 3 stomachs that were examined consisted mainly of unicellular algæ, but fragments of worms and winged insects also were present.

This fish is known from the Pacific slope of southern Mexico and Guatemala, and it is now for the first time recorded from El Salvador. According to Günther (1866) and subsequent authors this species also occurs in "western Ecuador," but this quite evidently is a mistake, for Meek (Pub., Field Mus. Nat. Hist., Zoöl. Ser., X, 1914) did not get it in Costa Rica; Meek and Hildebrand (Pub., Field Mus. Nat. Hist., Zoöl. Ser., X, 1916) did not take it in Panama; and Eigenmann (Memoir., Carnegie Mus., IX, 1922) does not record it in "The Fishes of Western South America." The specimens from El Salvador were taken in the Rio Molino, tributary to the Rio de Paz, near Ahuachapan. It was not found in the basins of the Rio Lempa and the Rio San Miguel, indicating that the species may reach the southermost limits of its distribution in the basin of the Rio de Paz.

Family V. PŒCILIIDÆ

The Top Minnows

Body elongate, compressed posteriorly; head more or less depressed above; anal fin in the male modified, the anterior rays becoming more or less united and usually produced, forming an organ for the transmission of the sperms to the genital opening of the female; species small; viviparous.

Many genera belonging to this family have been described by Regan, Eigenmann, Henn, and recently by Hubbs, based mainly upon the minute structure of the modified anal fins of the males. The number of genera that have been proposed, particularly in consideration of Hubbs's recent additions (Misc. Pub., Mus. Zoöl., Univ. Mich., No. 13, 1924, pp. 5–11), is rapidly approaching the total number of species recognized. Geiser (Amer. Midl. Nat., VIII, 1923, 175–188, with 18 figs.), in his studies of the minute structure of the modified anal fins ("Gonopod") of the Gambusia of the United States, which, by most recent authors, have been considered all identical as to species, has shown that three and possibly four divisions may be made. If the microscopic structure of the intromittent organ is used as a generic character, each species, as described and figured by Geiser (it would appear from the work of Hubbs, at least), should also constitute a genus. The use of the structure of this organ alone, as a generic character, obviously results in too many divisions, and the genus loses its value as a convenience in classification.

The author is of the opinion that the intromittent organs could be grouped as to general type or gross structure and thus serve a useful purpose, in combination with other characters, in defining genera; as, for example, in Mollienesia the modified portion of the fin is not greatly produced and it has a membranous covering (sometimes referred to as a hood), which covers or shields the anterior part of the organ, but which is distally free. In Gambusia, on the other hand, the intromittent organ is notably produced and the membranous hood is wanting. The characters of the intromittent organ in these genera are supported by the comparatively long, convoluted intestine in Mollienesia, while Gambusia has a short intestine, which is not convoluted. The minute structure of the intromittent organ would then become of specific value only, and it is believed that less confusion would result than by retaining and adding to the already too numerous very closely related "genera."

Some of the species of this family—as, for example, the Gambusia of the United States—have been found to be of great value as eradicators of mosquito larvæ. Limited observations made in the field, as well as the examination of stomach contents, indicate that all the species of this family occurring in El Salvador are of value as destroyers of mosquitoes.

KEY TO THE GENERA

a. Intestinal canal longer than the total length of the body, usually more or less convoluted; dorsal fin in adult male very high; the intromittent organ not much produced, shorter than head, anteriorly shielded by a short membranous hood................*Mollienesia*, p. 255.

aa. Intestinal canal not longer than the length of body and not convoluted; dorsal fin in males not much, if any higher than in females; the intromittent organ greatly produced, longer than head, and without a membranous hood........................*Priapichthys*, p. 258.

7. Genus **MOLLIENESIA** Le Sueur

Mollienesia Le Sueur, Jour., Ac. Nat. Sci., Phila., II, 1821, 3 (type *Mollienesia latipinna* Le Sueur).

Body elongate, rather robust; head more or less depressed; mouth transverse; teeth in the jaws in bands, the outer ones movable; dorsal fin elongate in the adult male, much higher than in the female; intromittent organ short, not as long as head, anteriorly shielded by a membranous hood; intestinal canal convoluted and longer than the total length of the fish. A single variable and rather widely distributed species was taken in the waters of El Salvador.

7. **Mollienesia sphenops** (Cuvier and Valenciennes)

CHIMBOLA

Pœcilia sphenops Cuvier and Valenciennes, Hist. Nat. Poiss., XVIII, 1846, 130, Pl. DXXVI, fig. 2 (Vera Cruz, Mexico); Regan, Biol. Cent. Amer., Pisces, 1907, 102, Pl. XIII, figs. 1–7.
Xiphophorus gilli Kner and Steindachner, Abhandl. k. Bayer, Ak. Wiss. München, X, 1864, 25, Pl. IV, fig. 1 (Rio Chagres, Panama).
Platypœcilus mentalis Gill, Proc., Ac. Nat. Sci., Phila., 1876, 335 (Panama).
Pœcilia boucardi Steindachner, Sitzb. k. Ak. Wiss., Wien, LXXVI, 1878, 386, Pl. III, fig. 263 (Colon, Panama).
Pœcilia salvatoris Regan, Ann. and Mag. Nat. Hist., 7 ser., XIX, 1907, 65, and Biol. Cent. Amer., Pisces, 1907, 104, Pl. XIV, figs. 2 and 3 ("Salvador").
Platypœcilus tropicus Meek, Pub., Field Col. Mus., Zoöl. Ser., VII, 1907, 146 (Turrialba, Costa Rica).
Pœcilia tenuis Meek, Pub., Field Col. Mus., Zoöl. Ser., VII, 1907, 147 (Tiribi; San Jose and Rio Maria Aguilar, Costa Rica).
Mollienesia sphenops tropica Meek, Pub., Field Mus. Nat. Hist., Zoöl. Ser., X, 1914, 116 (Costa Rica).

Head 3 to 4.25; depth 2.75 to 3.65; D. 9 to 11; A. 8 to 10; scales 25 to 29.

Body rather robust, variable, compressed; caudal peduncle strongly compressed, its depth 1.1 to 1.85 in head; head depressed, flat above, broader than deep over middle of eyes; snout broad, its length 2.8 to 3.6 in head; eye 3 to 4.4; interorbital 1.65 to 2.35; mouth transverse, directed slightly upward; lower jaw a little the longer; teeth in bands, the outer ones movable, enlarged, slightly broadened, curved inward, and well separated from the inner, minute, villiform ones; scales cycloid, enlarged ones present on head and snout, 11 or 12 in median series from occiput to dorsal, 8 complete longitudinal rows between dorsal and anal; dorsal fin with convex margin, occasionally nearly straight, the origin in females and young a little in advance of the anal and a little nearer the base of caudal than posterior margin of eye; dorsal much higher in the adult male and situated slightly farther forward, quite as near the eye as the base of caudal; caudal fin strongly convex to nearly straight; anal fin small, its origin in female slightly nearer base of caudal than eye, farther forward in adult males, usually an eye's diameter nearer tip of snout than base of caudal, and modified into a copulatory organ, but not greatly produced, always shorter than head, the produced portion anteriorly with a sort of membranous hood, which is free distally, the third, fourth, and fifth rays produced, 2 branches each of the anterior and median produced rays reaching the end of the organ, the branches of the anterior ray with small antrorse hooks at tip, the posterior branch of the median produced ray with 8 or 9 prominent spurlike hooks below the apex of the organ, the posterior produced ray not quite reaching the apex, both branches coterminal, each bearing a small posterior hook; ventral fins in the female moderate, inserted about equidistant from margin of opercle and end of anal base, reaching vent in large examples, to origin of anal in small ones, the third ray somewhat produced in the male and reaching beyond the base of fin; pectoral fins moderate, 1 to 1.8 in head.

Color variable, fresh females 54 millimeters long, dark olivaceous above; lower part of sides silvery with bluish reflections; pale underneath; scales on sides with indications of rusty spots; dorsal red with black spots near base; caudal greenish with faint elongate dark spots; anal and ventrals plain; pectorals slightly greenish. Color of male, 37 millimeters long, identical except for more red and larger and more pronounced black spots on dorsal fin. Some specimens plain without spots; others with prominent dark spots along the rows of scales on median part of sides; still others with pronounced brick-red spots (pale in spirits) along the rows of scales on sides; an occasional specimen with irregular dark blotches on sides; many specimens with plain to faint pale crossbars; a dark caudal spot frequently present; dorsal fin usually spotted with black, the spots varying in number, size, and intensity; caudal fin frequently plain but oftener with elongate dark spots.

Many specimens of this species, ranging from 10 to 120 millimeters in length, were preserved. It is the most abundant and the most universally distributed of all the fishes of the Republic. It was taken in every locality except in the Rio Molino, in which collections were made in fresh water. It was found in lakes, swamps, and streams, and it does not shun currents to the extent that most top minnows do, but it evidently finds the environment of the quieter waters more congenial, as it is found there in greatest abundance. This fish occurs mainly in shallow water, but it is also found along the shores in water several feet deep. It is abundant among vegetation and frequently, also, along rocky shores. This species was found to be especially abundant in Lakes Chanmico, Chalchuapa, and Coatepeque. In Lake Guija it was common along the shores but less numerous than its smaller, spotted relative, *Priapichthys letonai.* In Lake Olomega *M. sphenops* was less abundant than in any other lake visited, notwithstanding that

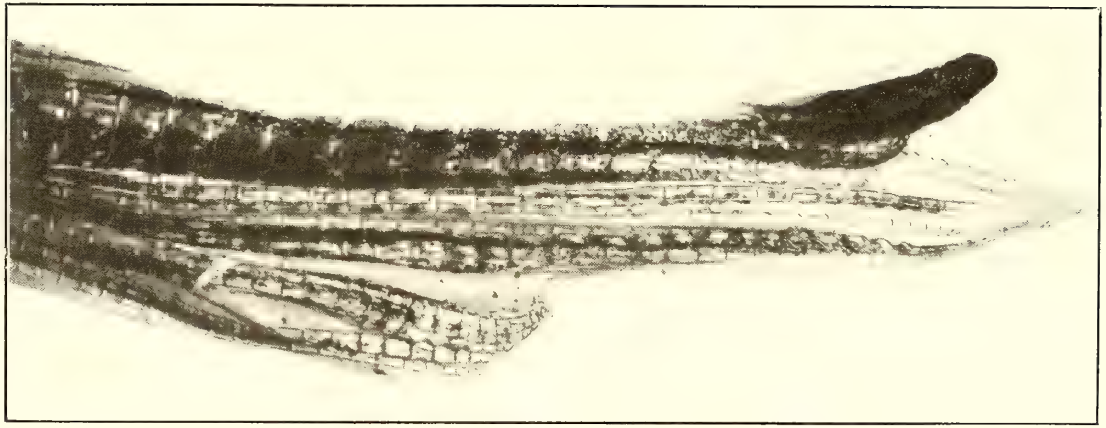

Fig. 11.—Distal part of the anal fin of the male *Mollienesia sphenops*, greatly magnified

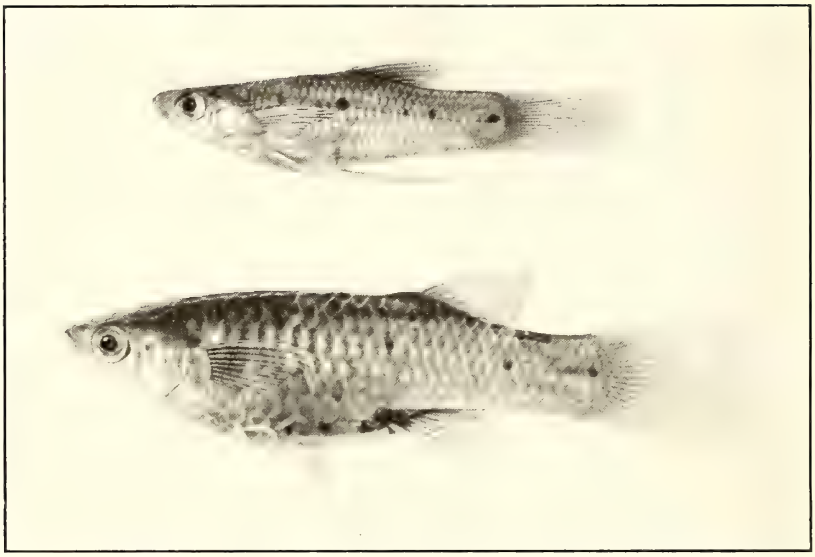

Fig. 12.—*Priapichthys letonai* sp. nov. Upper figure is the male. From the type. Length, 42 millimeters. Lower figure is the female. From a specimen 58 millimeters long

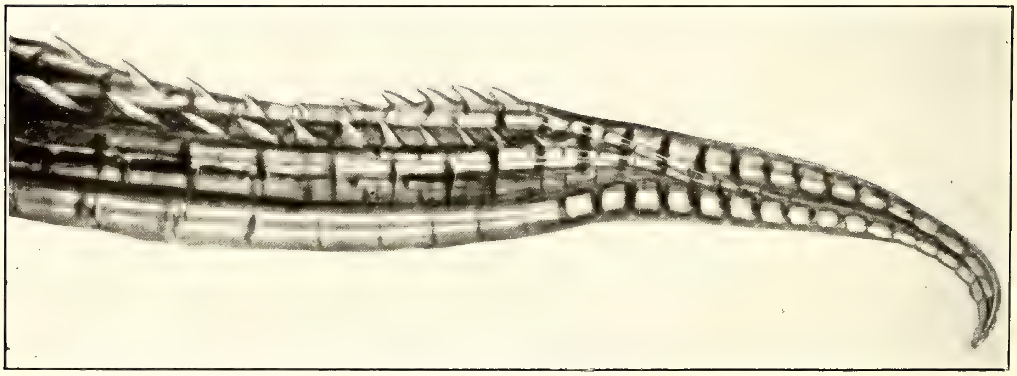

Fig. 13.—Distal part of the anal fin of the male *Priapichthys letonai* sp. nov., greatly magnified

the conditions for its development appeared to be ideal. Water birds, however, are extremely abundant on this lake and the fish probably are unable to protect themselves against these enemies.

The size attained by this species varies greatly in the different waters. The largest fish seen, ranging upward to 120 millimeters in length, were taken in small ponds at El Angel. Many large individuals were also taken in Lakes Guija, Coatepeque, and Ilopango. In Lakes Chanmico and Zapotitan, on the other hand, the usual size is rather small, the fishes ranging upward to only 55 millimeters in length. In this species, as in most top minnows, the males are smaller than the females, and sexual maturity is reached at a smaller size. Males 35 millimeters long appear to be fully mature, while the smallest mature female, among a limited number examined, was 60 millimeters. The males, as usual among the fishes of this group, are greatly in the minority. A lot of 245 fish gathered up at random after a discharge of dynamite on Lake Chanmico contained 80 males.

A comparatively small number of the fish collected appear to be gravid, indicating that the period (January and February) during which the collections were made was not the principal spawning season. Only a single stage of development of the egg or embryo was found in any one ovary, indicating that broods of young probably are not born in such rapid succession as in some of the other species of top minnows. The largest number of embryos found was 82, which were taken from the ovary of a fish 90 millimeters long.

The intestinal canal is about one-third longer than the total length of the fish. The contents of the stomachs of 24 specimens examined consisted mainly of disorganized masses, containing a relatively large amount of sand and some plant fragments, fragments of insects, minute ova (probably insect eggs), and in a few instances small quantities of Entomostraca. The species is used for mosquito control in Nicaragua by Sanitary Engineer F. E. Hulse, of the International Health Board, apparently with success, but it is believed from the field observations made, and from the examination of stomach contents, that its relatives, *Priapichthys letonai* and *P. fosteri,* are more efficient agents for the control of the malaria-transmitting mosquitoes, Anopheles.

This fish, as here understood, is a widely distributed, variable species, several nominal species having been defined. Much variation exists with respect to the depth of the body, shape of the dorsal and caudal fins, and especially with respect to color. These characters, however, appear to intergrade. Careful measurements and scale and fin counts were made of 40 specimens, selected to include all the extremes of variations. The minute structure of the intromittent organ, which is regarded as a very helpful character in determining species, was critically studied in all the extreme color phases represented among the El Salvador specimens, and this organ also was compared with others taken from specimens from Nicaragua and Panama and found to be identical. The range, as here understood, includes both slopes from southern Mexico to northern Colombia. This is one of a very few species of fishes that have previously been recorded from the fresh waters of El Salvador. Our specimens were collected in the following localities: Lake Guija, Rio del Desague, Lake Metapan, Lake Chalchuapa, Rio Pampe near Chalchuapa, Lake Ahuachapan, Lake Coatepeque, Lake Chanmica, Rio Sucio near Sitio del

Niño, Lake Zapotitan, ponds at El Angel, Lake Ilopango, small streams near San Salvador, Rio Lempa at Suchitoto and San Marcos, Rio San Miguel at San Miguel, and Lake Olomega.

8. Genus PRIAPICHTHYS Regan

Priapichthys Regan, Proc., Zoöl. Soc. London, 1913, 991 (type *Gambusia annectens* Regan).

Body elongate, head depressed above; mouth transverse; teeth in the jaws in narrow bands, the outer ones scarcely movable; dorsal fin in the adult male scarcely higher than in the female; intromittent organ greatly produced, longer than the head; alimentary canal not exceeding the length of the body and without convolutions. Two species, both apparently new, appear to belong to this genus.

KEY TO THE SPECIES

a. Dorsal fin in the female usually equidistant from the tip of snout and end of caudal, or slightly nearer the former; two branches of the median produced ray of the intromittent organ bearing spur-like hooks; median line of sides with a row of round black spots scarcely as large as the pupil, varying in number from 3 to 10 *letonai,* sp. nov., p. 258.

aa. Dorsal fin in the female, usually an eye's diameter nearer the end of caudal than tip of snout; only one branch of the median produced ray of the intromittent organ with spur-like hooks; sides with 6 to 10 dark crossbars *fosteri,* sp. nov., p. 260.

8. **Priapichthys letonai** sp. nov.

CHIMBOLA

Type No. 87251, U.S.N.M.; male, length 42 mm., Rio San Miguel, San Miguel.

Head 3.1 to 4.3; depth 3.15 to 4.05; D. 8 or 9; A. 9 or 10; scales 28 to 30.

Body moderately compressed anteriorly; caudal peduncle strongly compressed, its depth 1.35 to 2.35 in head; profile nearly straight from snout to nape, slightly convex from nape to dorsal; head rather broad, flat above; snout short, broad, 2.75 to 4.65 in head; eye 2.5 to 4.25; interorbital 2.2 to 3.28; mouth small, the cleft transverse; teeth loosely attached, the outer series slightly broadened, curved inward, and well separated from the very minute inner teeth; scales cycloid, present on head and snout and on base of caudal, each scale with 11 to 20 radii, average of 30 scales taken from 10 specimens ranging in length from 24 to 63 millimeters, 13.7; origin of dorsal in female a little in advance of middle of anal base, equidistant from tip of snout and end of caudal, or a little nearer the former; dorsal placed further forward in the adult male, about half the length of head, nearer tip of snout than end of caudal; caudal fin broad, gently convex; anal fin in females and young similar to dorsal, its origin a little nearer base of caudal than posterior margin of eye; anal fin in adult males inserted far in advance of dorsal, greatly produced, much longer than the head, reaching nearly to base of caudal in sexually mature but small males, proportionately shorter in larger specimens, the third, fourth, and fifth rays all of about equal length, the branches greatly crowded distally and forming a compound curve, the apex being directed forward, two of the branches of the median produced ray bearing about 12 spur-like hooks on their posterior margins; ventrals reaching vent in small females, proportionately shorter in large specimens, reaching past origin of anal in males; pectoral fins moderate, 1 to 1.85 in head; vertebræ about 15 + 17; alimentary canal about as long as the body; peritoneum black.

Color of the sexes similar; olivaceous above; lower part of sides silvery; median line of sides with a row of round black spots scarcely as large as pupil, varying in number from 3 to 10, present even in the mature embryo (wanting only on a single large female); a faint dark vertebral band; a sharp dark median line from anal to caudal; base of anal sometimes surrounded by black in large females; fins all unspotted; dorsal, caudal, and anal olivaceous; other fins plain translucent.

Many specimens of this species, ranging in length from 10 to 85 millimeters, were preserved. This fish inhabits both lakes and streams, but it was not taken in the tributaries of the Rio de Paz nor in Lakes Chalchuapa, Ahuachapan, Coatepeque, Chanmico, and Ilopango. Neither was it obtained in the Rio Lempa at San Marcos, notwithstanding that the species appeared to be common in that stream about 200 kilometers further upstream at the village of Suchitoto.

This fish appears to grow much larger in some localities than in others. In Lake Zapotitan, for example, the largest male and female obtained were, respectively, 20 and 27 millimeters in length, yet fully mature, as shown by the completely developed intromittent organ of the male and by the presence of large embryos in the ovaries of the female. Specimens of this size from some of the other localities at which collections were made are clearly sexually immature. The largest fish seen, ranging a little more than 80 millimeters in length, were taken in the Rio San Miguel at San Miguel. The males are much smaller than the female and they occurred rather sparingly in the catches made.

Many of the specimens in the collection (taken during January and February) are in spawning condition, the ovary usually containing large eggs in two distinct stages of development, in addition to smaller ova. An ovary taken from a specimen 67 millimeters long, for example, contained 26 well-developed embryos and 30 apparently fully mature eggs, measuring about 1.5 millimeters in diameter, and minute ova. The young fish when born is from 8 to 10 millimeters long, and well developed. The body is covered with dark punctulations, which usually are concentrated in about three places on the median line of the sides, later forming the dark lateral spots which are characteristic of the species.

Stomachs examined contained insects, fragments of fresh-water sponge, algæ, leaf fragments, small ova (probably insect eggs), and inorganic matter consisting largely of sand. Field observations would indicate that the species probably is of considerable value as an eradicator of mosquito larvæ.

The specimens were obtained at the following localities: Lake Guija, Rio del Desague at Lake Guija, Lake Metapan, Lake Zapotitan, Rio Sucio at Sitio del Niño, Rio Acelhuate at San Salvador, Rio Lempa at Suchitoto, Rio San Miguel at San Miguel, and Lake Olomega.

9. **Priapichthys fosteri** sp. nov.

CHIMBOLA

Type No. 87263, U.S.N.M.; male, length 38 mm., Rio Lempa, San Marcos.

Head, 2.95 to 5.2; depth, 3.25 to 4.8; D., 8; A., 9 or 10; scales, 27 to 30.

Body moderately compressed anteriorly; caudal peduncle deep and strongly compressed, 1.4 to 1.8 in head; profile straight from snout to nape, gently convex from nape to dorsal; head broad, flat above; snout short, broad, 3.2 to 4.25 in head; eye, 2.7 to 3.7; interorbital, 1.85 to 2.9; mouth small, the cleft transverse; teeth loosely attached, the outer series slightly broadened, curved inward, and well separated from the very minute inner teeth; scales cycloid, present on head and snout and on base of caudal, each scale with 6 to 11 radii; average of 30 scales taken from 10 specimens, ranging from 23 to 61 millimeters in length, 8.86+; origin of dorsal in female a little in advance of middle of anal, occasionally equidistant from the tip of snout and the end of caudal, but more usually an eye's diameter nearer the latter; dorsal placed further forward in adult male, about an eye's diameter nearer tip of snout than end of caudal; caudal fin broadly rounded; anal fin in females and young similar to the dorsal, its origin about equidistant from tip of snout and base of caudal; anal fin in adult males inserted far in advance of dorsal, greatly produced, much longer than head, failing to reach base of caudal by a distance equal to the length of snout and eye, the third, fourth, and fifth rays all of about equal length, the branches greatly crowded distally and forming a compound curve, the apex being directed forward, the posterior branch of the median produced ray bearing about 16 spurlike hooks on its posterior margin; ventral fins reaching origin of anal in young, scarcely to vent in adult females, past the origin of anal in males; pectoral fins moderate, 1 to 1.35 in head; vertebrae 15+17; alimentary canal scarcely as long as body; peritoneum black.

Color of the sexes similar; upper parts greenish; lower parts silvery; sides with from 6 to 10 dark crossbars; a narrow vertebral line; a sharp dark median line from anal to caudal; ventral fins yellowish; other fins all slightly olivaceous.

This species is represented by 98 specimens, ranging from 35 to 80 millimeters in length. It was taken only in the Rio Lempa at San Marcos and at Suchitoto in quiet water, and 2 specimens were secured in brackish water in the estuary at El Triunfo. The males in this species, as is usual for the family, are much smaller than the females and fewer in number.

Many of the specimens collected (during January and February) were in spawning condition. Embryos and eggs of several sizes usually were present in one ovary. The ovary from a female 80 millimeters long, for example, contained 44 well-developed embryos, 42 "eyed" eggs, and 44 large, probably mature, eggs. Two other ovaries contained, respectively, 7 large embryos and 20 eggs in the "eyed" stage in addition to smaller ova.

The stomachs examined contained principally fragments of insects and vegetable débris. The species is quite probably of value as an eradicator of mosquito larvæ.

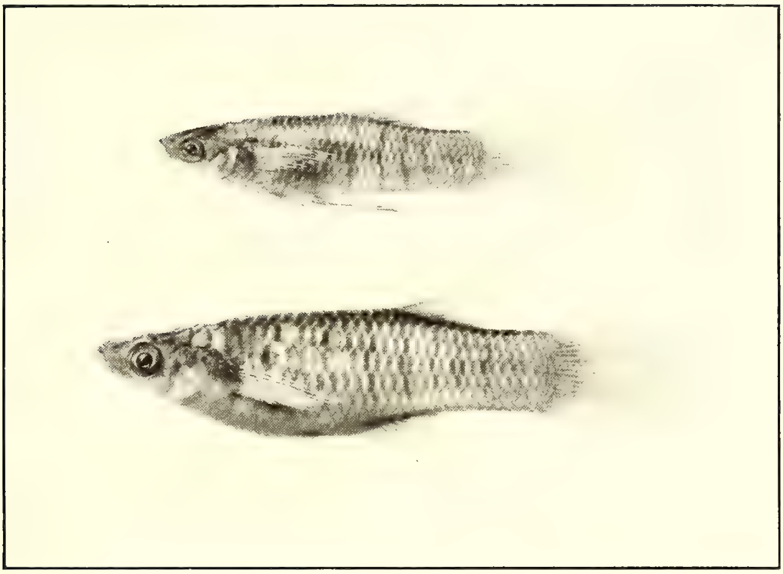

Fig. 14.—*Priapichthys fosteri* sp. nov. Upper figure is the male. From the type. Length, 38 millimeters. Lower figure is the female. From a specimen 50 millimeters long

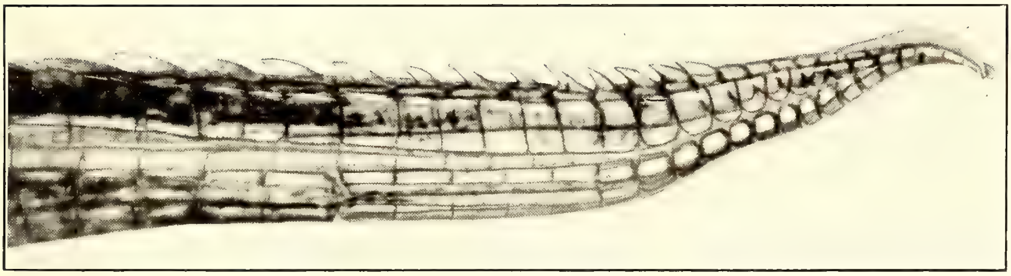

Fig. 15.—Distal part of the anal fin of the male *Priapichthys fosteri* sp. nov., greatly magnified

This fish differs notably in color from the preceding one, but in structure the two are very similar. The dorsal fin, however, appears to be inserted slightly further backward in the female in the present species, usually being an eye's diameter nearer the end of the caudal than the tip of the snout, instead of being equi-distant or nearer the snout. The scales, on an average, possess fewer radii in the present species, as shown by Figure 16, and in the distal part of the intromittent organ of the male, in which only one branch of the produced rays bears spurlike hooks, while in the preceding species two of the branches have hooks. This species also appears to be related to *Priapichthys panamensis*, Meek and Hildebrand (Pub., Field Mus. Nat. Hist., Vol. X, 1916, p. 322), from which it differs in the relative position of the dorsal and anal fins, the shape of the caudal, and in the shape and structure of the produced portion of the anal fin.

The specimens were obtained in the Rio Lempa, at San Marcos and Suchitoto, and in brackish water at El Triunfo.

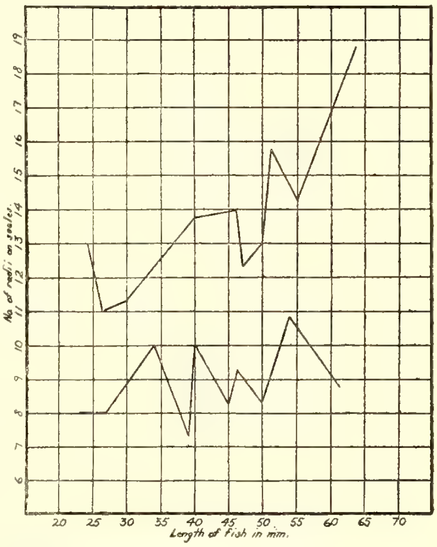

FIG. 16.—Upper figure, *Priapichthys fosteri* sp. nov.; lower figure, *Priapichthys letonai* sp. nov. Each point in the graph is based on the average number of radii on three scales from one specimen. The scales were taken below the dorsal fin—one above, one in, and one below the lateral line

Family VI. ANABLEPIDÆ

Cuatro-ojos

Body elongate, depressed anteriorly, compressed posteriorly; head broad; supraorbital rims much raised; eye divided into an upper and a lower portion by a dark-colored transverse membrane in the cornea; mouth mostly transverse; premaxillaries protractile; teeth in each jaw in a villiform band; scales small or of moderate size; dorsal and anal fins short; anal fin of the male modified into a thick scaly conical organ with an orifice at its extremity. This family consists of a single genus.

9. Genus ANABLEPS Scopoli

Anableps Scopoli, Introd. Hist. Nat., 1777, 450 (type *Cobitis anableps* Linnæus).

The characters of the genus are included in the family description. The eye in these fish is divided into an upper and a lower half by a dark horizontal partition in the cornea. The upper half of the eye is higher than the rest of the head, is usually exposed above the surface of the water, and evidently is for seeing in the air, while the lower portion is for use in the water. It is from this singular structure and function of the eye that the name "Cuatro-ojo," or four-eye, has originated. A single species is known from Central American waters.

10. **Anableps dovii** Gill

FOUR-EYE; CUATRO-OJO

Anableps dowei Gill, Proc., Ac. Nat. Sci., Phila., 1861(1862), 4 (Panama; where it quite certainly does not occur).
Anableps dovii Regan, Biol. Cent. Amer., Pisces, 1907, 108.

Head 3.6 to 4.3; depth 4.4 to 7.5; D. 8 to 10; A. 10, rarely 9; scales 62 to 73.

Body very elongate, notably depressed anteriorly, compressed posteriorly; depth of caudal peduncle 2.2 to 3 in head; head strongly depressed, flat above, its depth between eyes about half its width; snout broad, its length 2.9 to 4 in head; eye rather large, the cornea with a somewhat thickened, black, longitudinal bar in the middle, dividing the eye into an upper and a lower half, its diameter, 3.6 to 5.9 in head; interorbital deeply concave, 3.3 to 5.55 in head; mouth broad, almost wholly transverse; premaxillaries broad, excessively protractile; maxillary rather broad, reaching anterior margin of eye; teeth small, in a broad villiform band in each jaw; scales rather small, enlarged on head; dorsal small, situated posteriorly, its origin at least an eye's diameter behind vertical from end of anal base; caudal fin rather broadly rounded; anal fin similar to the dorsal, its origin about equidistant from margin of opercle and tip of caudal in adult, much further forward in young, modified into an intromittent organ in the male, the anterior rays enveloped in loose scaly skin, extending to the end of the longest rays, where there is a perforation; ventral fins short, reaching to or a little past the vent in the young, failing to reach this point in the adult, pectoral fins moderate, 1.25 to 1.6 in head.

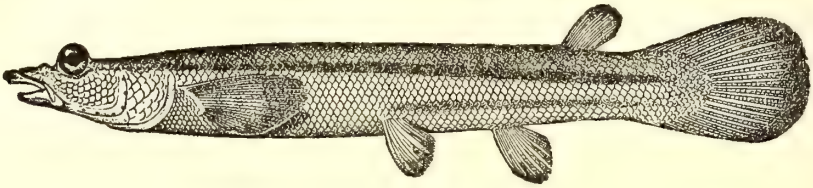

FIG. 17.—*Anableps dovii* Gill

Color of a fresh specimen, 115 millimeters long, dark greenish above; white underneath; sides with a white lateral band about half as wide as eye, bordered above and below by black; back crossed by several indistinct black bars; eye with a median black stripe, the upper half dark, the lower half white; dorsal dark green; caudal somewhat lighter green, with black on distal parts; anal, ventrals, and pectorals light greenish, the pectorals with black on lower half. In larger examples the lateral band is yellow and it is broken up into spots anteriorly.

This species is represented by 36 specimens, ranging from 50 to 235 millimeters in length. It is common in some localities but scarce or wanting in others. It inhabits both lakes and streams. In the streams it is partial to the quieter places. This species is especially common in Lake Guija and in the outlet, the Rio del Desague. It is also very common in the Rio Lempa in the vicinity of Suchitoto. A single fish was seen and captured in salt water at the wharf at Cutuco. The fish swim at the surface with the upper half—that is, the portion above a dark longitudinal band of the modified superior eye—above water, and they are usually seen in small schools. They are rather shy, and when frightened they sometimes make leaps of a meter or so above the water, or, more usually, they lift the head and body above the surface, leaving only the tail in the water. In this way they make rapid headway, and repeated efforts at surrounding a school with a 9-meter seine failed.

The four-eye apparently is never used for food, although it reaches a much larger size than several other species that are eaten. The largest fish seen by the collectors was 235 millimeters long, but according to the natives at Lake Guija the species attains a length of at least 300 millimeters. The male appears to be smaller than the female, as no males occurred among the larger individuals examined. The largest male seen was 180 millimeters long.

The species is viviparous, and the anal fin in the male serves as a copulatory organ. As the fish develops and reaches sexual maturity the anterior rays of the fin become enveloped in scaly skin, which extends to the end of the longest rays, forming a sort of tube, and having an orifice distally. A thin membranous receptacle lies in the abdominal cavity at the base of the anal, which is entered by the posterior end of the testes. A tube extends into the modified anal fin from this receptacle. This tube lies either right or left of the eveloped fin rays, through which the seminal fluid is conveyed to the distal orifice. The ovary is single, and the number of young produced at one time appears to be rather small. One ovary contained 6 embryos, each approximately 11 millimeters long; another inclosed only two embryos, each about 14 millimeters long.

This fish appears to feed on algæ and small entomostracans, insects, and other animals found among these plants at the surface of the water. The contents of the stomachs examined and the habit of surface feeding and swimming indicate that this species may be of value as an eradicator of mosquito larvæ.

This fish is known from Southern Mexico, Guatemala, and El Salvador. The type locality given by Gill, who first described the species, is the "Pacific coast of Panama," where the species quite certainly does not occur. It is more probable that the single specimen upon which the description was based came from Guatemala or Mexico, where Captain Dow, for whom the species is named, also collected. The specimens at hand were collected in Lake Guija and its outlet, Rio Lempa at Suchitoto and San Marcos, Rio San Miguel at San Miguel, Lake Olomega, and Cutuco. It was also seen in the Rio Sucio at Sitio del Niño, but no specimens were obtained there.

Order PERCOMORPHI

Family VII. ATHERINIDÆ

The Silversides

Body elongate, more or less compressed; premaxillaries protractile; jaws with two or more series of conical teeth; lateral line usually absent, never complete; two well-separated dorsal fins, the first formed of 3 to 6 slender spines, the second with a short spine and 7 to 13 branched rays; caudal fin forked; anal fin with a single spine and 12 or more branched rays; ventral fins abdominal, each with a spine and 5 branched rays; vertebræ more than 30; sides with a silvery longitudinal band.

This is a large family of small fishes. Some of the members inhabit fresh water, but the majority of them live in salt and brackish water.

10. Genus THYRINA Jordan and Culver

Thyrina Jordan and Culver, Proc., Cal. Ac. Sci., 2 ser., V, 1895, 419 (type *Thyrina evermanni* Jordan and Culver).
Melaniris Meek, Pub., Field Col. Mus., Zoöl. Ser., III, 1902, 117 (type *Melaniris balsanus* Meek).

Body elongate, compressed; trunk sharply compressed ventrally; profile in advance of dorsal almost straight and nearly parallel with the posterior half of the ventral contour; lower jaw included; teeth unequal, the outer ones more or less enlarged in each jaw; scales often crenate, particularly on the back; origin of first dorsal well behind the origin of anal; base of anal longer than head; pectoral fins rather long, frequently longer than head.

A single species, which appears to be undescribed, was taken in fresh water.

11. **Thyrina guija** sp. nov.

PEPESCA; MANJUDA; ALFILER; ROVALETE

Type No. 87273, U.S.N.M.; length 88 mm., Lake Guija, El Salvador.

Head 4 to 4.75; depth 5.5 to 6.65; D. III to V–8 to 10; A. I, 22 to 26; scales 43 to 47.

Body very elongate, compressed; abdomen rather sharply compressed, almost but not quite forming a keel; caudal peduncle long and slender, at least twice as long as deep, its least depth 2.55 to 3.8 in head; head rather short, flat above; snout moderate, its length 2.9 to 3.2 in head; eye 2.9 to 3.5; interorbital 2.4 to 2.7; mouth small; the small hidden maxillary reaching nearly to anterior margin of eye; premaxillary fully protractile, the anterior margin strongly curved, posteriorly greatly extended; lower jaw included, a little shorter than the upper; teeth in jaws in bands, the outer series in each jaw enlarged, those of the upper jaw more so than in the lower jaw and placed on the extreme outer edge of the jaw, curved inward and exposed when the mouth is closed; gill rakers short, about 16 on lower limb of first arch; scales mostly with straight edges, those on back with rather broad indentations, small scales extending on base of dorsal but none on the other fins; origin of spinous dorsal over the base of about the sixth ray of the anal, the spines reaching less than half the way to origin of soft dorsal; origin of the soft dorsal over or a little behind middle of anal base and about half as far from base of caudal as the margin of opercle; caudal fin forked, the lower lobe larger and longer; anal fin long, its base extending slightly beyond the end of the base of second dorsal, origin of anal about equidistant from posterior half of eye and base of caudal; ventral fins small, inserted about equidistant from margin of opercle and base of caudal; pectoral fins longer than head, falcate, 3.45 to 4.25 in length of body; vertebræ 20 + 20.

Color greenish above, silvery below; sides with a silvery lateral band, about the width of the pupil, with a dark margin above; the scales on the back with dusky punctulations; a dark vertebral line; upper surface of head dusky; fins mostly pale green to translucent; a dark line along base of anal.

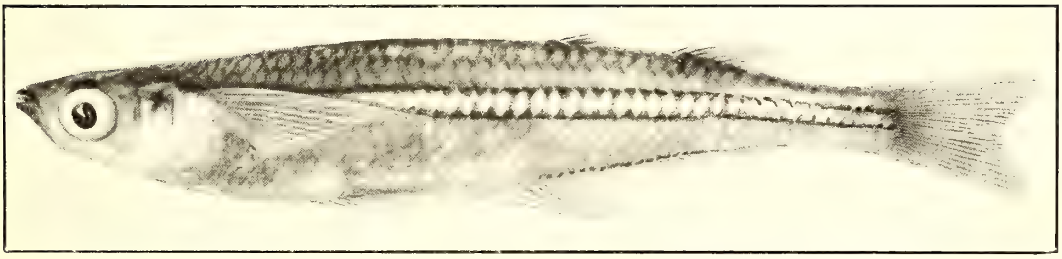

FIG. 18.—*Thyrina guija* sp. nov. From the type. Length, 88 millimeters

Many specimens, ranging from 20 to 105 millimeters in length, were preserved. This fish was taken only in Lake Guija, its outlet, and in two localities on the Rio Lempa. It appeared to be common in the Rio del Desague, the stream forming the outlet of Lake Guija. In the other localities where the species was found it appeared to be rather rare.

This fish appears to differ from *T. guatemalensis* (Günther), recorded from the Pacific slope of Guatemala, according to the very inadequate descriptions of that species, in having a more slender body, more numerous scales in a lateral series, and a slightly inferior mouth. According to Günther (Proc., Zoöl. Soc., London, 1864, p. 151) *T. guatemalensis* has only 36 scales in a lateral series. Regan (Biol. Cent. Amer., Pisces, 1907, p. 64) gives 36 to 42. Jordan and Hubbs (Leland Stanf. Jr. Univ. Pub., Univ. Ser., 1919, pp. 58 and 60), however, are of the opinion that Regan was considering three species under one name, and therefore the range given by him may not be correct.

In the present species the range in the number of scales, based upon the enumeration of 30 specimens, is 43 to 47. The mouth in *guatemalensis* is described as terminal, while in the species at hand the lower jaw is included and is a little shorter than the upper. The depth of the body in the length in *guatemalensis* is given as 5 by Günther and 4 to 5 by Regan. In the present species the depth is contained from 5.5 to 6.65 times in the length.

Eight small specimens, taken in salt water in the estuary at Triunfo, agree fairly well with this species, except that the scales above the median line of the side, at least, have broad indentations, and the number in the lateral series appears to be a little lower, 41 to 43. These fish are referred to the present species, although further study and more specimens may show that they belong to a distinct species.

The contents of 4 stomachs examined consisted of insects and insect larvæ, entomostracans, and filaments of algæ. The sexual organs were in a collapsed state, showing that the spawning season was not near at hand when the specimens were collected (January and February).

The specimens are from Lake Guija, Rio del Desague near Lake Guija, and from the Rio Lempa at Suchitoto and San Marcos.

Family VIII. MUGILIDÆ

The Mullets

Body elongate, more or less compressed; mouth small, terminal or inferior; teeth, if present, small, various in form; premaxillaries protractile; gill openings wide, the membranes free from the isthmus; gills 4, a slit behind the fourth; lateral line usually absent, never complete; scales large, extending forward on head; dorsal fins 2, well separated; first dorsal composed of 4 rather strong spines; second dorsal with I, 7 to 10 rays; anal fin with II or III, 7 to 11 rays; caudal fin forked; ventral fins abdominal, each with I, 5 rays. Most of the species of this family are marine but several are strictly fresh water in their habits.

KEY TO THE GENERA

a. Stomach muscular, gizzard-like; teeth minute, slender; lower jaw angulate in front; anal with 3 spines, except in very young .... *Mugil*, p. 266.

aa. Stomach not gizzard-like; teeth in villiform bands on jaws and vomer; lower jaw anteriorly rounded; anal fin with 2 spines .... *Agonostomus*, p. 267.

11. Genus MUGIL Linnæus

Mugil Linnæus, Syst. Nat., Ed. X, 1758, 316 (type *Mugil cephalus* Linnæus).
Querimanna Jordan and Gilbert, Proc., U. S. Nat. Mus. V, 1882 (1883), 588 (type *Myxus harengus* Günther).

Body rather robust, the back and belly rounded; head broad; mouth terminal; jaws weak, the lower one with a median obtuse angle; teeth in the jaws minute, flexible; eye large, with an adipose lid; scales large, extending forward on head; anal spines 3 (2 in very young); stomach very muscular, gizzardlike. The species of this genus are marine, but some of them enter fresh water and the one included here appears to be a regular visitor to the fresh-water streams of El Salvador, where it is of some commercial importance and highly prized as a food fish.

12. Mugil cephalus (Linnæus)

"Liebre Ancha;" "Liza"

Mugil cephalus Linnæus, Syst. Nat. Ed. X, 1758, 316 (Europe; based on Artedi); Jorden and Evermann, Bull., U. S. Nat. Mus. XLVII, 1896, 811, Pl. CXXVI, fig. 343; Meek and Hildebrand, Pub., Field Mus. Nat. Hist., Zoöl. Ser., XV, 1923, 275. (For a fuller synonymy and additional references see one of the two last-mentioned works.)

Head 3.9 to 4.1; depth 3.9 to 3.96; D. IV–I, 8; A. III, 8; scales 42.

Body elongate, compressed; head low and rather broad; snout tapering, its length 3.2 to 3.45 in head; eye 4.35 to 4.9; interorbital slightly convex, 2.2; mouth rather broad, oblique; upper jaw projecting; maxillary scarcely reaching eye, 3.6 to 3.75 in head; teeth in the jaws minute but visible with the unaided eye; gill rakers minute, close-set; scales moderate, 11 or 12 rows between origin of second dorsal and base of anal, each scale with a finely serrate membranous border; origin of spinous dorsal slightly nearer tip of snout than base of caudal, the longest spine 1.8 to 1.9 in head; origin of second dorsal about an eye's diameter nearer origin of first dorsal than base of caudal; the fin with a few small scales at the base posterior to the anterior rays; caudal fin forked, the upper lobe longest, pointed, the fin with small scales; anal fin similar to the second dorsal, its origin a little in advance of second dorsal, with a few minute scales at base posterior to the anterior rays; ventral fins inserted under the posterior fourth of the pectorals; pectoral fins a little longer than the ventrals, failing to reach origin of first dorsal, 1.5 in head.

Color of a fresh specimen, 430 millimeters long, dark greenish brown above; lower parts silvery; rows of scales on sides with dark stripes; fins all dusky, except anal and ventrals, which are pale.

Two specimens, respectively 410 and 430 millimeters in length, were taken. This fish, although a salt-water species, occasionally runs upstream into fresh water. The specimens at hand were taken in the Rio Lempa at Suchitoto, about 180 kilometers, following the course of the stream, from the sea and far above the influence of tide. According to local fishermen this fish is a more or less permanent resident and it is not infrequently taken. It occurs in the market in the village, and it was served on the table in a local hotel during our visit. Fish up to 500 millimeters in length are said to be taken locally. This fish was not seen elsewhere.

This widely distributed mullet is known from nearly all warm waters of both hemispheres—on the American coasts from Monterey to Chile and from Cape Cod to Brazil. The El Salvadorian specimens were taken in the Rio Lempa at Suchitoto.

12. Genus AGONOSTOMUS Bennett

Agonostomus Bennett, Proc., Zoöl. Soc., London, I, 1830 (1831), 166 (type *Agonostomus telfairii* Bennett).
Neomugil Vaillant, Bull., Soc. Philom., Paris, IV, 1894, 73 (type *Neomugil digueti* Vaillant).

Body elongate, compressed; mouth terminal in young, subinferior in adult; cleft extending laterally to or past front of eye; lower lip never greatly thickened; teeth in bands on jaws, vomer, and palatines; anal spines 2, the first one minute, often hidden in the skin; stomach not gizzardlike. The species of this genus inhabit mostly tropical rivers, some of them living in mountain torrents. A single species was taken in El Salvador.

13. Agonostomus monticola (Bancroft)

TEPEMECHIN; CHIMBERA; LIZA

Mugil monticola Bancroft, in Griffith's edition, Cuvier's Animal Kingdom, Fishes, 1836, 367, pl. 36 (West Indies).
Agonostomus monticola Günther, Cat. Fish. Brit. Mus., III, 1861, 464.
Agonostomus nasutum Günther, Cat. Fish. Brit. Mus., III, 1861, 463 (Rio San Geronimo, Guatemala).
Neomugil digueti Vaillant, Bull., Soc. Philom., IV, 1894, 73 (Lower California).
Agonostomus salvini Regan, Ann. and Mag. Nat. Hist., 7 ser., XIX, 1907, 66, and Biol. Cent. Amer., Pisces, 1907, 68, Pl. XI, fig. 2 (Nacasil, Guatemala).

Head 3.9; depth 3.8; D. IV–I, 8; A. II, 10; scales 42.

Body elongate, moderately compressed; upper profile gently convex; head rather small; snout rather long, pointed, 3.4 to 3.55 in head; eye 3.4 to 4.1; interorbital 2.55 to 3.1; mouth moderate, nearly horizontal; upper jaw projecting; upper lip moderately thickened in a large specimen, rather thin in a smaller one; maxillary reaching a little past anterior margin of eye but scarcely to pupil, 2.85 to 3.1 in head; teeth small in bands on jaws, vomer, and palatines; gill rakers about half as long as eye, 19 on lower limb of first arch; scales rather large, strongly ctenoid, extending forward on interorbital, present on cheeks, 11 or 12 longitudinal rows between origin of second dorsal and base of anal; origin of spinous dorsal at least an eye's diameter nearer tip of snout than base of caudal, the spines strong, the anterior one a little longer than eye and snout, 1.55 to 1.6 in head; origin of second dorsal about an eye's diameter nearer the origin of the first than the base of the caudal, the outer margin of the fin concave; margin of caudal fin rather deeply concave; anal fin similar to the second dorsal but somewhat larger, its origin a little in advance of second dorsal; ventral fins moderate, inserted under or slightly posterior to middle of pectorals; pectoral fins a little longer than the ventrals, reaching to or a little beyond vertical from origin of spinous dorsal, 1.3 to 1.55 in head.

Color of a fresh specimen, 180 millimeter long, grayish black above; sides silvery; under parts pale silvery; scales on sides with dark edges; an indistinct dark blotch at base of caudal; first dorsal with dark spines and yellow interradial membranes; second dorsal greenish, with a broad translucent margin; caudal and pectorals plain translucent; the latter dark at base; anal and ventrals mostly yellowish; iris golden. A smaller specimen, 82 millimeters long, lighter, the black on margins of scales on sides not continuous, forming specks; caudal spot more distinct.

Two specimens of this species, respectively 82 and 180 millimeters in length were taken. It is improbable that this fish is as scarce as indicated by the few specimens secured, for it appears to be well known to the native fishermen, according to whom the species occurs in streams in several localities where it was not taken by us. One of our specimens was taken in a deep rocky place in the Rio del Desague, a short distance below Lake Guija, of which this river is the outlet. The smaller specimen was taken in quiet shallow water on a sandy bottom in the Rio Lempa at San Marcos.

According to the fishermen at Lake Guija the "Tepemechin" spawns in June. The eggs are much sought and considered a great delicacy. One fish is said to produce a quantity of eggs, which in bulk is greater than that of the entire fish. The species, according to native fishermen, reaches a length of about 250 millimeters.

This species, as here understood, ranges from southern Mexico to Panama, occurring on both slopes of Central America and Panama. It is also known from the West Indies. The specimens at hand are from the Rio del Desague, near Lake Guija, and from the Rio Lempa at San Marcos.

Family IX. CENTROPOMIDÆ

The Robalos

Body moderately elongate, compressed; head long, somewhat depressed above; mouth large, protractile; lower jaw projecting; teeth in villiform bands on jaws, vomer, and palatines; preopercle and supraclavicle serrate; preopercle with a ridge, usually bearing 2 spines; opercle without spines, produced as a flap; lateral line more or less arched, continued to end of caudal fin; scales small or of moderate size, ctenoid; two separate dorsal fins; the first consisting of 7 or 8 spines; second dorsal with 1 spine and 8 to 11 branched rays; caudal fin forked; anal short, with 3 spines and 6 or 7 branched rays; ventral fins inserted behind base of pectorals, with I, 5 rays; pectoral fins symmetrical; air bladder large, with or without appendages.

All the species of this family are American and are included in one genus.

13. Genus CENTROPOMUS Lacépède

Centropomus Lacépède, Hist. Nat. Poiss., IV, 1803, 248 (type *Sciæna undecimalis* Bloch).
Oxylabrax Bleeker, Arch. Neerl. Sci. Nat., XI, 1876, 264 (type *Sciæna undecimalis* Bloch).
Macrocephalus Bleeker, Arch. Neerl. Sci. Nat., XI, 1876, 336 (type *Sciæna undecimalis* Bloch).

The characters of the genus are included in the family description. The species of this genus are game fishes. Some of them reach a large size, and the quality of the flesh is excellent. They are chiefly shore fishes, frequenting brackish water, and some of them ascend fresh-water streams. Three species were secured in fresh water in El Salvador; others, no doubt, occur there from time to time.

KEY TO THE SPECIES

a. Scales small, 72 to 75 in a lateral series, about 8 rows between the middle of second dorsal and lateral line; gill rakers few, about 8 on lower limb of first arch------*nigrescens*, p. 269.

aa. Scales larger, not more than 65 in a lateral series, 5 or 6 rows between middle of second dorsal and lateral line; gill rakers more numerous, not fewer than 12 on lower limb of first arch.

  b. Scales moderate, 52 to 54 in a lateral series; gill rakers numerous, 16 or 17 on lower limb of first arch; angle of preopercle with 2 abruptly enlarged serræ; lateral line not in a dark streak------*robalito*, p. 270.

  bb. Scales smaller, 58 to 62 in a lateral series; gill rakers fewer, 13 or 14 on lower limb of first arch; angle of preopercle with several gradually enlarged serræ; lateral line in a black streak------*pectinatus*, p. 271.

14. **Centropomus nigrescens** (Günther)

ROBALO; ROVALO

Centropomus nigrescens Günther, Proc., Zoöl. Soc., London, 1864, 144, and Trans., Zoöl. Soc., London, VI, 1868, 407 ("Chiapam", Pacific coast of Guatemala); Jordan and Evermann, Bull., U. S. Nat. Mus., XLVII, 1896, 1119; Regan, Biol. Cent. Amer., Pisces, 1907, 50; Meek and Hildebrand, Pub., Field Mus. Nat. Hist., Zoöl. Ser., XV, Part II, 1925, 426, Pl. XLII.

Centropomus viridis Lockington, Proc., Cal. Ac. Sci., VII, 1876 (1877), 110 (Off Ascunsion Island).

Centropomus undecimalis (not of Bloch) Gilbert and Starks, Memoir., Cal. Ac. Aci., IV, 1904, 89.

Head 3 to 3.1; depth 3.7 to 3.85; D. VIII–I, 9; A. III, 6; scales 72 to 75.

Body elongate, compressed; profile concave over eyes; caudal peduncle long, its least depth 2.75 in head; head long; snout broad, its length, 3.36 to 3.6 in head; eye 7.55 to 9; interorbital 4.75; mouth large, oblique; lower jaw strongly projecting; maxillary reaching nearly opposite middle of eye, 2.25 to 2.3 in head; preorbital with a few small serræ; preopercle strongly serrate, several serræ at angle enlarged; preopercular ridge without spines; gill rakers rather long and few, 8 on lower limb of first arch; scales rather small, about 8 rows between middle of base of second dorsal and lateral line, not greatly reduced in advance of dorsal, small scales extending on base of all fins, except spinous dorsal; origin of spinous dorsal nearly twice the diameter of eye behind base of pectorals, the spines moderate, the third and fourth of about equal length, the former not reaching the tip of the latter when deflexed, the length 2.05 to 2.5 in head; origin of second dorsal notably nearer base of caudal than preopercular margin; caudal fin forked, both lobes rather acute; origin of anal under middle of base of second dorsal, the second spine somewhat enlarged, not reaching the tip of the third when deflexed, 2.75 to 3.25 in head; ventral fins inserted about an eye's diameter behind base of pectorals, failing to reach vent; pectoral fins reaching about to the beginning of the distal third of ventrals, 1.9 to 1.95 in head.

Color of a fresh specimen, 715 millimeters long, bluish silvery above; lower part of sides and abdomen silvery; upper surface of head and sides in advance of pectorals yellowish; lateral line in a black streak; dorsals, caudal, and anal bluish black; second dorsal, caudal, and anal with pale margins; pectorals and ventrals yellowish green; ventrals with a broad white margin.

Several large individuals, ranging upward to 715 millimeters in length, were taken with dynamite in the Rio Lempa at San Marcos. Only one specimen, 475 millimeters long, was preserved, which, together with notes and measurements made in the field on still larger specimens, serves as the basis for the above description.

The "Rovalo" was reported by local inhabitants from several localities and streams in El Salvador, but, as already stated, it was taken only in one locality. Native fishermen at Suchitoto claimed that "Rovalo" exceeding a meter in length are occasionally taken there in the Rio Lempa. It is probable that this species and possibly several others of this genus ascend the river to and beyond that locality, as most of the representatives ascend fresh-water streams freely.

This species is known from Lower California to Ecuador. In El Salvador it was taken in the Rio Lempa at San Marcos.

15. **Centropomus robalito** Jordan and Gilbert

ROBALO; ROVALO

Centropomus armatus Günther (not Gill) Trans., Zoöl. Soc., London, 1868, 408.

Centropomus robalito Jordan and Gilbert, Proc., U. S. Nat. Mus., IV, 1881 (1882), 462 (Mazatlan; Acapulco); Jordan and Evermann, Bull., U. S. Nat. Mus., XLVII, 1896, 1123.

Head 3 to 3.1; depth 3.25 to 3.4; D. VIII–I, 10; A. III, 6; scales 52 to 54.

Body moderately elongate, compressed; back elevated; head long, rather flat above; snout long and broad, its length 2.75 to 3 in head; eye 4 to 4.15; interorbital 4.75 to 6.8; mouth large, a little oblique, lower jaw strongly projecting; maxillary reaching nearly opposite middle of eye, 2.35 to 2.45 in head; preorbital with small serrations; preopercle strongly serrate, 2 serræ at angle notably enlarged; preopercular ridge with 2 spines at angle; gill rakers slender, rather numerous, 16 or 17 on lower limb of first arch; scales moderate, ctenoid, 5 or 5½ rows between middle of second dorsal and lateral line, reduced in advance of dorsal, about 14 rows crossing the back anterior to spinous dorsal, small scales extending on base of second dorsal, caudal, and anal; origin of first dorsal scarcely an eye's diameter behind base of pectorals, the third spine about equal in length to the fourth but not reaching beyond it when deflexed, 1.55 to 1.65 in head; origin of second dorsal about equidistant from preopercular margin and base of caudal; caudal fin forked, both lobes acute; origin of anal fin slightly posterior to middle of base of second dorsal, the second spine much enlarged, reaching somewhat beyond base of caudal when deflexed, its length 1.15 in head; ventral fins inserted slightly behind base of pectorals, reaching to or a little beyond vent; pectorals not quite reaching tips of ventrals, 1.35 to 1.6 in head.

Color bluish gray above, silvery below; lateral line not in a black streak; fins all more or less dusky; spinous dorsal usually with more or less black on interradial membranes; membrane between second and third anal spine, with black next to the third spine.

Several small specimens, ranging in length from 120 to 140 millimeters, were seined in the Rio Lempa at San Marcos in strictly fresh water and well beyond the influence of tides. One small specimen of this species was taken in an estuary at Triunfo.

This fish ranges from Lower California to Panama. The specimens from El Salvador are from the Rio Lempa at San Marcos, and from salt water at Triunfo.

16. **Centropomus pectinatus** Poey

ROBALO; ROVALO

Centropomus undecimalis Cuvier and Valenciennes (part), Hist. Nat. Poiss., II, 1828, 102.

Centropomus pectinatus Poey, Memorias, II, 1860, 121 (Cuba); Jordan and Evermann, Bull., U. S. Nat. Mus., XLVII, 1896. 1122; Regan, Biol. Cent. Amer., Pisces, 1907, 46; Meek and Hildebrand, Pub., Field Mus. Nat. Hist., Zoöl. Ser., XV, Part II, 1925, 421.

Centropomus medius Günther, Proc., Zoöl. Soc., London, 1864, 144, and Trans., Zoöl. Soc., London, VI, 1868, 406 ("Chiapam," Pacific coast of Guatemala).

Centropomus grandoculatus Jenkins and Evermann, Proc., U. S. Nat. Mus. XI, 1888 (1889), 139 (Guaymas).

Head 3 to 3.15; depth 3.5 to 3.7; D. VIII–I, 10; A. III, 7; scales 58 to 62.

Body elongate, compressed; profile concave over eyes; caudal peduncle long, its least depth 2.55 to 2.8 in head; head long; snout rather broad, its length 2.8 to 2.9 in head; eye 4.15 to 5.1; interorbital 4.45 to 5.6; mouth large, oblique; lower jaw strongly projecting; maxillary reaching nearly opposite middle of eye, 2.2 to 2.35 in head; preorbital with small serrations; preopercle strongly serrate, several serræ at angle enlarged; preopercular ridge with 2 spines at angle; gill rakers slender, 13 or 14 on lower limb of first arch; scales of moderate size, 5½ or 6 rows between middle of base of second dorsal and lateral line, somewhat reduced in advance of dorsal, about 14 rows crossing the back anterior to spinous dorsal, small scales extending on base of second dorsal, caudal, and anal; origin of spinous dorsal an eye's diameter behind base of pectorals, the spines long, the third the longest, reaching to or a little beyond the tip of the fourth when deflexed, 1.5 to 1.7 in head; origin of second dorsal a little nearer base of caudal than preopercular margin; caudal fin forked, both lobes acute; origin of anal fin under the posterior third of second dorsal, the second spine much enlarged but not reaching beyond the tip of the third when deflexed, 1.3 to 1.6 in head; ventral fins inserted less than an eye's diameter behind base of pectorals, reaching to or a little beyond vent; pectoral fins reaching somewhat past middle of ventrals, 1.7 to 1.75 in head.

Color bluish or grayish above; sides and abdomen silvery; tip of snout dusky; lateral line in a black streak; dorsals, caudal, and anal all more or less dusky; the membrane between the second and third anal spines darker than rest of fin but not black; ventrals and pectorals yellowish green; tips of ventrals black in young, this color disappearing with age.

Three specimens of this species, respectively 220, 280, and 350 millimeters in length, were preserved. The largest of these was taken in strictly fresh water in the Rio Lempa at San Marcos.

This species occurs on both coasts of tropical America where it enters fresh water freely. On the Atlantic it ranges from Cuba to Panama and on the Pacific from Guaymas to Colombia.

The El Salvador specimens are from the Rio Lempa at San Marcos and from the salt water estuary at Triunfo.

Order CHROMIDES

Family X. CICHLIDÆ

The Mojarras

Body elongate, compressed; mouth large or small, terminal or subinferior; teeth conical, incisorlike or lobate; vomer and palatines without teeth; premaxillaries freely protractile; nostrils single on each side; lateral line interrupted under soft dorsal, reappearing lower down on side; scales usually ctenoid; dorsal fin single, the spinous portion usually longer than the soft part; anal fin with 3 or more spines; ventral fins thoracic, with I, 5 rays; pseudobranchiæ wanting; branchiostegals 5 or 6; air bladder present. A single genus of this large family of tropical fresh-water fishes is represented in the collection from El Salvador.

14. Genus CICHLASOMA Swainson

Cichlasoma Swainson, Nat. Hist. Class., Fish., II, 1839, 230 (type *Labrus punctatus*).
Heros Heckel, Ann., Mus. Wien, II, 1840, 362 (type *Heros severus* Heckel).
Hoplarchus Kaup. Arch. Naturg. XXVI, 1860, 128 (type *Hoplarchus pentacanthus*).

Body deep or elongate, compressed; mouth small or moderate; teeth on jaws in bands, the outer ones more or less enlarged, sometimes forming canines; maxillary exposed or not; premaxillary processes shorter than head; opercle entire; gill rakers short and few (6 to 15 on lower limb of first arch); lateral line interrupted; scales moderate or large, usually ctenoid, extending forward on head to the eyes or beyond, also present on cheeks and opercles; dorsal fin single, not notched, with XIV to XIX, 7 to 12 rays; anal IV to XII, 6 to 14; caudal round, truncate or emarginate; ventrals inserted below or a little behind base of pectorals; pectoral fins asymmetrical, with 12 to 18 rays.

This is a large genus with many representatives in Mexico, Central and South America. Five species are represented in the collections from El Salvador.

KEY TO THE SPECIES

a. The outer teeth anteriorly in each jaw more or less regularly enlarged; premaxillary processes not reaching middle of eye; mouth small, the maxillary failing to reach anterior margin of eye.
  b. Dorsal XVII to XIX, 8 or 9; anal VIII to X, 5 to 8; body with black crossbars, the two bands anterior to dorsal arched forward .... *nigrofasciatum*, p. 273.
  bb. Dorsal XIV to XVI, 12 to 14; anal V, 9 or 10; body with dark crossbars (at least in young), none of them arched.
    c. Body deep, the depth 1.8 to 1.95 in length (specimens 30 to 85 mm. long); profile steep; eye large, 2.5 to 2.8 in head (specimens 30 to 85 mm. long); general color bluish gray above, pale silvery below; sides with 8 moderately distinct crossbars .... *macracanthus*, p. 274.
    cc. Body more slender, the depth 2 to 2.25; profile less strongly elevated; eye smaller, 3.6 to 4.95 in head; general color darker; the crossbars (in young) more distinct .... *meeki*, sp. nov., p. 275.

aa. Anterior pair of teeth in upper jaw enlarged, canine-like; the anterior pair in lower jaw small, followed by one or more enlarged teeth; premaxillary processes reaching to or beyond middle of eye; mouth moderate, the maxillary reaching about to anterior margin of eye; dorsal XVII to XIX, 10 to 12; anal VII or VIII, 8 to 10.

d. Body rather deep, the depth 2.12 to 2.47 in length (specimens 127 to 185 mm. long); about 6 rows of scales on cheek; a prominent dark spot above origin of lateral line (sometimes obscure in adults); no black sports or bars on opercle; no rusty spots on body and vertical fins_____________________________________*trimaculatum*, p. 277.

dd. Body more elongate, the depth 2.54 to 2.74 in length (specimens 127 to 185 mm. long); about 8 rows of scales on cheek; no dark spot above origin of lateral line; opercle with one or two bars or blotches; adults usually with rusty spots on body and vertical fins____*motaguense*, p. 279.

17. **Cichlasoma nigrofasciatum** Günther

BURRO; ACHIBA; CHAMARRA; CHINCOYO; CONGA; MOJARRA

Heros nigrofasciatus Günther, Trans., Zoöl., Soc., London, VI, 1868, 452, Pl. LXXIV, fig. 3 (Lakes Atitlan and Amatitlan).
Cichlasoma nigrofasciatum Jordan and Evermann, Bull., U. S. Nat. Mus. XLVII, 1898, 1525; Regan, Ann. and Mag. Nat. Hist., 7 ser., XVI, 1905, 75; Regan, Biol. Cent. Amer., Pisces, 1906, 22; Meek, Pub., Field Col. Mus., Zoöl. Ser., VII, 1908, 189.

Head 2.55 to 3.35; depth 1.9 to 2.25; D. XVII to XIX, 8 or 9; A. VIII to X, 5 to 8; scales 27 to 30.

Body compressed, short and deep; dorsal profile rather steep, only slightly convex over snout and eyes; caudal peduncle short and deep, 1.7 to 2.5 in head; head rather small; snout moderate, 2.4 to 3.3 in head; eye 3.2 to 4.6; interorbital 2.05 to 3.4; mouth small, terminal; maxillary hidden, failing to reach anterior margin of eye, 3.25 to 4.15 in head; fold of lower jaw interrupted at symphysis; premaxillary processes extending to anterior margin of eye; teeth in the jaws in bands, conical, the outer ones in anterior part of each jaw enlarged; gill rakers short, 7 to 9 on lower limb of first arch; scales rather large, somewhat reduced on nape and chest, about 4 or 5 rows on the cheeks, 4 complete rows between origin of dorsal and lateral line, a few small scales on the base of vertical fins; dorsal fin long, not notched, the last spine longest, about equal to postorbital part of head, the soft part elevated, the median rays filamentous in adults, sometimes reaching nearly to end of caudal, origin of fin over margin of opercle; caudal fin broadly rounded; anal fin with strong pungent spines, the soft part similar to that of the dorsal and coterminal with it; ventral fins inserted slightly behind the base of pectorals, the exterior rays more or less filiform, except in very young, and reaching beyond origin of anal; pectoral fins moderate, reaching to or more usually past the origin of anal, 1.05 to 1.4 in head; vertebræ 13 + 15.

Color of a fresh specimen, 55 millimeters long, grayish green above; pale with pinkish and silvery reflections on lower parts of sides; chest and abdomen nearly black with a slight greenish tinge; snout black; sides with 9 black bars, usually broader than interspaces, the first band arched, running across the nape and on opercle, a second band concentric with the first and extending across nape to behind base of pectorals, the third bar short, usually nearly and frequently completely connecting with the second bar on median line of side, forming a V; the other bars nearly vertical, the fourth to the seventh usually extending on dorsal fin, the eighth connecting the ends of the dorsal and anal, the last one at base of caudal; ventral fins black; all other fins dusky. Some individuals are much darker than others, but the pattern is identical. The specimen described is one of the dark-colored ones. These color varieties are recognized by the natives who, on Lake Chalchuapa, at least, referred to the light variety as "plateada" and the dark ones as "negra."

Many specimens of this common species, ranging in length from 25 to 120 millimeters, were preserved. This fish is the most common one of the family in the fresh waters of El Salvador. However, it was not found in four localities visited, viz, Rio Molino at Ahuachapan, Lake Ahuachapan, Rio Lempa at San Marcos, and Lake Olomega. It is especially abundant in Lakes Coatepeque and Chanmico.

This species reaches a small size, probably rarely exceeding a length of 120 millimeters. It is used for food and also for crab bait. Its habitat does not appear to be limited to any definite type of bottom, depth, or vegetation. In Lake Coatepeque it was especially abundant among the rocks where, because of the very clear water, it could be seen at a depth upward of 6 meters. In other localities it was found in shallow water among vegetation and often in comparatively muddy places. The species, according to the contents of 9 stomachs examined, feeds on small animal and plant life of suitable size. Meek (Pub., Field Col. Mus., Zool. Ser., VII, 1908, p. 189) states that this fish deposits its eggs in April, May, and June in Lakes Amatitlan and Atitlan, Guatemala. The sexual organs in the specimens examined (taken in January and February) were mostly in the early stages of development, containing very minute ova that were not visible with the naked eye. A few specimens, however, contained eggs upward of 3 millimeters in diameter and probably nearing maturity.

This fish heretofore has been recorded only from Lakes Amatitlan and Atitlan, Guatemala, and it apparently had not been taken in streams. The specimens from El Salvador were collected in the following localities: Lake Guija, Lake Metapan, Lake Chalchuapa, Rio Pampe near Chalchuapa, Lake Coatepeque, Lake Chanmico, Lake Zapotitan, Rio Sucio at Sitio del Niño, ponds at El Angel, Lake Ilopango, Rio Lempa at Suchitoto, and Rio San Miguel at San Miguel.

18. **Cichlasoma macracanthus** (Günther)

MOJARRA

Heros macracanthus Günther, Proc., Zoöl. Soc., London, 1864, 153, and Trans., Zoöl. Soc., London, 1868, 451 (Chiapam; Huamuchal).

Cichlasoma macracanthum Jordan and Evermann, Bull., U. S. Nat. Mus., XLVII, 1898, 1518; Regan (part), Ann. and Mag. Nat. Hist., 7 ser., XVI, 1905, 241; Biol. Cent. Amer., Pisces, 1906, 24, Pl. V, fig. 1.

Head, 2.5 to 2.8; depth, 1.8 to 1.95; D. XV or XVI, 12 or 13; A. V, 9 or 10; scales, 30.

Body very deep, compressed; the dorsal profile strongly elevated, straight from snout to interorbital, then gently convex; caudal peduncle deep, its depth 2.2 to 2.55 in head; head moderate, deep; snout tapering, 2.7 to 2.8 in head; eye large, 2.5 to 2.8; interorbital 2.9 to 3.7; preorbital from two-thirds to three-fourths the length of eye; mouth small, terminal; maxillary covered by the preorbital, not reaching anterior margin of eye, its length 3.4 to 4.6 in head; premaxillary processes reaching anterior fourth of eye; lower lip without a definitely free margin at the

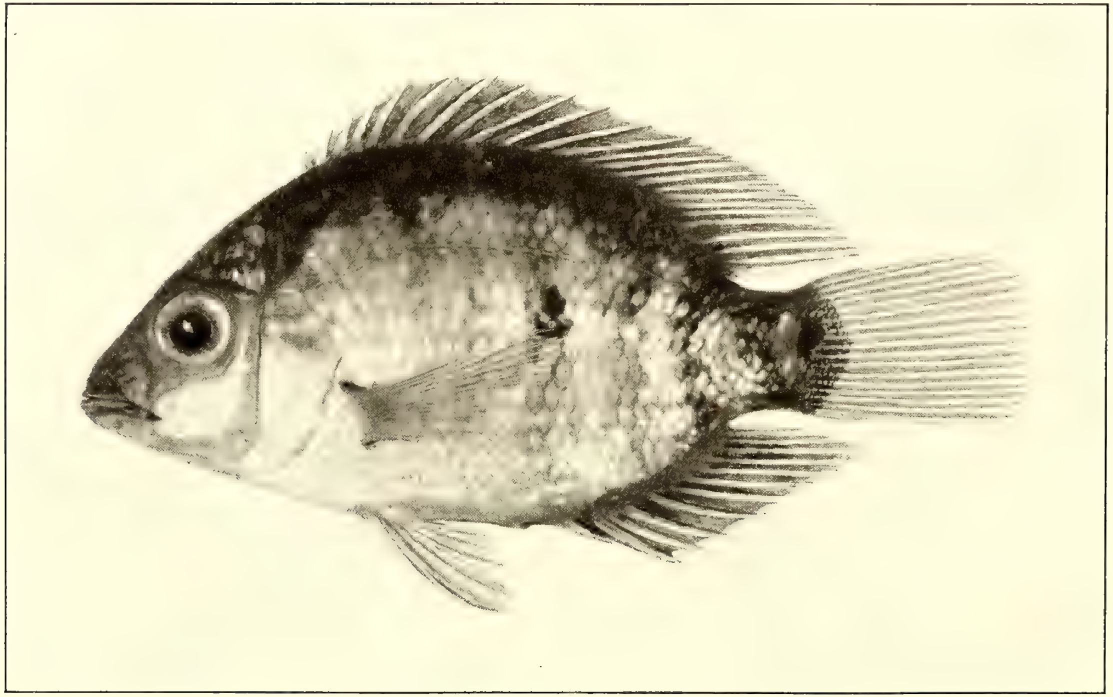

Fig. 19.—*Cichlasoma macracanthus.* From a specimen 78 millimeters long

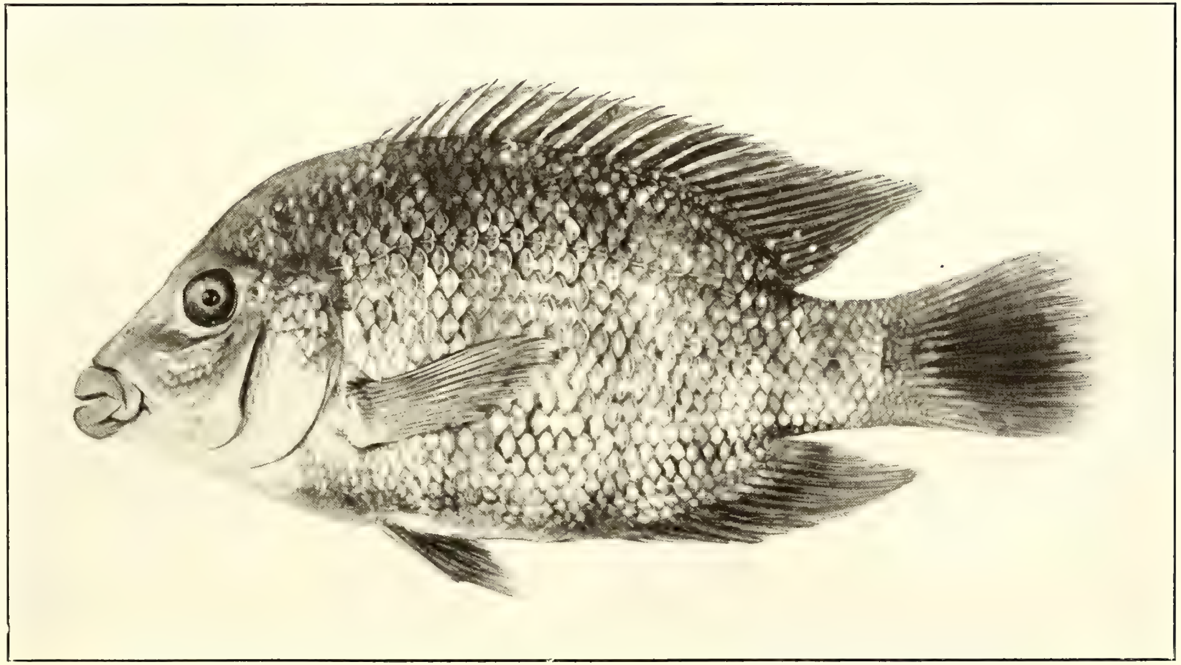

FIG. 20.—*Cichlasoma meeki* sp. nov. From the type. Length, 175 millimeters

symphysis; teeth in villiform bands in each jaw, the outer ones in each jaw anteriorly somewhat enlarged; gill rakers very short, about 6 on lower limb of first arch; scales moderate, 5 or 6 rows between origin of dorsal and lateral line, somewhat reduced on nape and chest, small scales extending on base of vertical fins, those above lateral line with smooth edges, those below lateral line with small spinules on posterior margin and on a part of the upper surface of the exposed portion; dorsal fin long, the spines graduated, the last one about half the length of head, origin of fin over margin of opercle; caudal fin rounded; anal fin with strong graduated spines, the last one a little longer and considerably stronger than the last dorsal spine, origin of fin about equidistant from base of pectorals and base of caudal; ventral fins inserted a little behind base of pectorals, reaching nearly or quite to origin of anal; pectoral fins reaching to or a little beyond origin of anal, 1.1 to 1.2 in head.

Color of fresh specimen bluish gray with silvery reflections above; lower parts pale silvery; sides with 8 dark crossbars, the fifth bar with an intensified black blotch on median line of sides; a black spot at base of caudal above lateral line; pectoral fins pinkish; all other fins dusky.

Nine small specimens, ranging in length from 30 to 85 millimeters, were preserved. These specimens agree fairly well with descriptions of *C. macracanthus*, a species first described from the western slope of Guatemala. The specimens at hand were taken in Lake Ahuachapan. This lake, although it has no visible outlet, is situated within the basin of the Rio de Paz, a stream forming a portion of the boundary between El Salvador and Guatemala.

This species has previously been recorded from the Pacific slope of Guatemala and Tequesixtlan, southern Mexico. The El Salvador specimens are from Lake Ahuachapan.

19. **Cichlasoma meeki** sp. nov.

MOJARRA; MOJARRA NEGRA; MOJARRA PLATEADA

Type No. 87301, U.S.N.M.; length 175 mm.; Lake Guija, El Salvador.

Head 2.4 to 3; depth 2 to 2.25; D. XIV or XV, 12 to 14; A. V, 9 or 10; scales 28 to 30.

Body moderately deep, compressed; dorsal profile rather strongly elevated, straight from snout to eye, then gently convex; adults of 200 millimeters and more in length with nuchal hump; caudal peduncle short and deep, its depth 1.95 to 2.6 in head; head moderate; snout rather long and pointed, longer than postorbital part of head, except in very young, 2.15 to 3.2 in head; eye small, 3.6 to 4.95; interorbital 2.5 to 3.6; preorbital as broad as eye in specimens about 160 millimeters long, proportionately broader in larger specimens and narrower in the young; mouth small, terminal; maxillary mostly covered by preorbital, failing to reach anterior margin of eye, 2.5 to 3.8 in head; lower lip with an uninterrupted free margin, the free part being very narrow at symphysis; premaxillary processes reaching anterior fourth of eye; teeth in the jaws in bands, mostly pointed, some of them in the larger specimens frequently worn and blunt, the outer ones in anterior part of jaws somewhat enlarged; gill rakers very short, 8 to 10 on lower limb of first arch more or less developed; scales moderate, 5 or 6 rows between origin of dorsal and lateral line, reduced in size on nape and chest, those above lateral line with smooth edges, those below lateral line with small spinules on margin and on portion of exposed part; dorsal fin long and continuous, the spines graduated, the last one scarcely half the length of head, proportionately somewhat shorter in the adult than in young; median rays of the soft portion produced in adults reaching opposite about middle of caudal, origin of fin slightly in advance of margin of opercle; caudal fin rounded, sometimes more or less truncate; anal spines strong, graduated, the last one much stronger and longer than the longest dorsal spine, the soft portion similar to that of the dorsal, origin of fin usually about an eye's diameter nearer base of pectorals than base of caudal; ventral fins inserted just behind base of pectorals, reaching to origin of anal in young, failing to reach this point in large specimens; pectoral fins usually reaching to or a little beyond origin of anal, 1.18 to 2.35 in head.

Color of a fresh specimen, 75 millimeters long, greenish silvery with bluish reflections above; lower parts silvery; snout greenish; sides with 6 indistinct dark crossbars, the third bar with a black blotch on median part of side; a black spot on upper half of base of caudal; ventrals slightly yellowish; all other fins olivaceous; iris yellow. In the young the black in each bar on the median part of sides is intensified and somewhat broadened, suggesting a lateral band. In large specimens the black bars on the sides, anteriorly at least, become very obscure, the black blotch in the third bar disappears, and the caudal spot becomes obscure and many of the scales on the sides bear greenish specks. Two color varieties, "Mojarra negra" and "Mojarra plateada," which, however, show no structural differences and which appear to intergrade, are recognized in some localities by the natives.

This common food fish is represented by many specimens, ranging from 25 to 220 millimeters in length. The writer, however, has found it impossible to identify the specimens with any known form and he believes them to represent a new species. The species is related to *C. macracanthus*, of which small specimens were obtained in Lake Ahuachapan. The present species, however, is more slender, the anterior profile less steep and convex, the eye is notably smaller, and the color, while variable, as shown in the description, is darker and the bands are more distinct. These differences are most noticeable when specimens of like size are compared.

This mojarra is one of the most important food fishes of the fresh waters of El Salvador, and it was taken, or reported, from nearly all waters visited. It is said to reach a length of about 320 millimeters. In Lake Metapan it appeared to be more common than elsewhere. A fisherman, who waded and used a cast net, caught about 24 of these fish, ranging in length from 140 to 305 millimeters, during 4 hours' fishing, and only a few of other species. The flesh of this fish is firm and of good flavor.

According to information obtained from the natives, this species spawns along shore in comparatively shallow water. A disagreement as to the time of spawning (some saying that the species spawned in May and June, others that it spawned in August) either shows that the spawning period is a protracted one or, more probably, that little is known about it. The specimens dissected, which were taken during

January and February, contained small ova, indicating that the spawning season was not near at hand. The contents of four stomachs examined consisted of the remains of fish, insects, insect larvæ, spicules of sponges, filaments of algæ, and fragments of higher plants.

The species is named in honor of the late Dr. Seth E. Meek, curator of fishes in the Field Museum of Natural History, who contributed much to our knowledge of the fishes of Mexico and Central America.

The specimens were collected in the following waters: Lake Guija, Lake Metapan, Lake Chalchuapa, Rio Sucio at Sitio del Niño, Rio Lempa at Suchitoto and San Marcos, Rio San Miguel at San Miguel, and Lake Olomega.

20. **Cichlasoma trimaculatum** (Günther)

GUAPOTE; MOJARRA; ISTATAGUA

Heros trimaculatus Günther, Trans., Zoöl. Soc., London, VI, 1868, 461, Pl. LXXVI (Chiapam and Huamuchal, Pacific slope, Guatemala); Jordan and Evermann, Bull., U. S. Nat. Mus., XLVII, 1898, 1529.

Cichlasoma trimaculatum Regan, Ann. and Mag. Nat. Hist., 7 ser., XVI, 1905, 333, and Biol. Cent. Amer., Pisces, 1906, 28.

Head 2.3 to 2.75; depth 2.1 to 2.45; D. XVII (rarely XVIII) 11 or 12; A. VII (rarely VIII) 8 to 10; scales 29 to 31.

Body moderately elongate, becoming proportionately deeper with age; profile nearly straight over the head in young, concave in adult; caudal peduncle much deeper than long, its least depth 2.3 to 2.9 in head; head not much longer than deep; snout rather pointed, 2.5 to 3.6 in head; eye 3.35 to 5; interorbital 2.3 to 3.8; preorbital about half the diameter of eye in young (specimen 55 millimeters long), nearly as broad as eye in adult (specimen 185 millimeters long); mouth moderate, oblique; lower jaw projecting; maxillary partly exposed, reaching about to vertical from anterior margin of eye, 2.65 to 3.85 in head; premaxillary process extending about to middle of eye; lower lip with its lower margin free throughout; teeth in the jaws pointed, the anterior pair in upper jaw enlarged, canine like, the anterior pair in lower jaw small, the next two pairs enlarged similar to the anterior pair in upper jaw; gill rakers short, 7 to 9 more or less developed on the lower limb of first arch; scales rather large, somewhat reduced on nape and chest, extending on base of vertical fins, 5 rows between origin of dorsal and lateral line, about 6 rows on cheeks; dorsal fin long, the spines graduated, the last a little more than one-third the length of head, the median soft rays produced, the filaments varying in length among individuals, sometimes reaching the end of caudal fin but usually shorter, the origin of fin over margin of opercle; caudal fin round; anal spines stronger than the dorsal spines, the longest one longer than the last dorsal spine, about 2.6 in head, the origin of fin about equidistant from base of pectoral and end of anal base; ventral fins reaching past origin of anal to base of third or fourth spine in the young, shorter in the adult, the outer ray usually more or less produced; pectoral fins reaching scarcely as far back as the ventrals, 1.3 to 1.65 in head.

Color variable, a fresh specimen, 270 millimeters long, olivaceous, with a large wine-colored area in pectoral region, extending on gill covers; sides with 5 blackish blue blotches, the anterior one above origin of lateral line and the last on upper half of base of caudal; fins all olivaceous, the pectorals paler than the other fins, the dorsal with wine-colored spots, caudal with a broad light margin, anal with a dark margin, ventrals with dark tips; iris brilliant red. Young, 40 millimeters long, greenish; sides with 7 indistinct dark bars, broader than the interspaces; a black blotch above origin of lateral line, another on median part of side above origin of anal, a third on upper half of base of caudal; fins olivaceous, the anal a little paler than the other fins, the median rays of ventrals dark. All of the smaller specimens and some of the larger ones have dark bars, or indications thereof, on the sides. Most of the larger specimens have 5 or 6 dark blotches on the sides, which in the plainer colored specimens, having no dark bars, are reduced to 3, viz, one above origin of lateral line, one on side above origin of anal, and the third on upper half of base of caudal.

Many specimens, ranging from 25 to 185 millimeters in length, were preserved. Only one specimen (185 millimeters long) has the exact color pattern described and figured by Günther in the original account of the species. Others, however, approach this pattern. In structure the present species is related to the other "Guapote," *C. motaguense*, common in certain lakes in El Salvador. *C. trimaculatum*, however, has a much deeper body, particularly in the adult. When a large series of various sizes is measured, however, due to variation in depth with age, the extremes for the two species, as shown in the description, overlap, but the average difference in depth remains evident. The average depth in the length of the body in 13 specimens of *C. trimaculatum*, ranging in length from 40 to 185 millimeters, is 2.57. In a similar series of *C. motaguense* it is 2.29. The difference in depth is not as great among the young as it is among larger fish. For example, in 5 specimens of *C. trimaculatum*, ranging in length from 127 to 185 millimeters, the range of the depth in the length is 2.12 to 2.47 (average 2.22). In *C. motaguense*, in an identical series, the range is 2.54 to 2.74 (average 2.65). In *C. trimaculatum* the head and snout are somewhat narrower and more pointed and the cheeks are not as deep and are provided with only about 6 rows of scales instead of about 8, as in *C. motaguense*. The differences in color, as shown in the description, are pronounced.

This species, although taken in streams in a few instances, is principally a lake fish. In Lakes Guija and Ilopango it is the most important food fish. The fish is said to reach a length of 355 millimeters, but the largest individual seen by us was only 270 millimeters long.

This "Guapote" is taken with hook and line, with trot lines, and with cast nets. In Lake Ilopango, a deep clear lake, the Indians, when fishing in deep water, dive and cast their nets under water. In the quality of its flesh this species ranks with the other "Guapote" (*C. motaguense*) taken in most lakes in El Salvador. It undoubtedly is the most handsome of all the fresh-water fishes of El Salvador, having both a pretty shape and pleasing color.

According to a native fisherman at Lake Ilopango this fish spawns from August to October in water varying from very shallow to 6 meters in depth. It builds nests, and the eggs and young are guarded by the adults for some time after hatching. The sexual organs in the specimens examined (taken during January) apparently were in the early stages of development, showing that the spawning season was not near at hand when the collections were made. The contents of 5 stomachs examined consisted of the remains of fish, snails, insect larvæ, and plant fragments.

This species heretofore has been recorded from western Guatemala. The specimens in the present collection are from Lake Metapan, Lake Guija, Rio Lempa at Suchitoto and San Marcos, Lake Ilopango, Rio San Miguel at San Miguel, and Lake Olomega.

21. **Cichlasoma motaguense** (Günther)

GUAPOTE; MORO; PANDO

Heros motaguensis Günther, Trans., Zoöl. Soc., London, VI, 1868, 462, Pl. LXXVII, fig. 2 (Rio Motagua, Guatemala); Jordan and Evermann, Bull., U. S. Nat. Mus., XLVII, 1898, 1534.

Cichlasoma motaguense Regan, Ann. and Mag. Nat. Hist., XVI, 1905, 336, and Biol. Cent. Amer., Pisces, 1906, 29.

Head 2.35 to 2.8; depth 2.2 to 3; D. XVII or XVIII (rarely XIX), 10 to 12; A. VII (rarely VIII) 8 to 10; scales 30 to 32.

Body comparatively elongate; dorsal profile gently convex over the eyes in young, a little concave in adults; caudal peduncle short, its depth 2.55 to 3 in head; head longer than deep; snout long, its length 2.4 to 2.7 in head; eye 3.25 to 6.1; interorbital 3 to 4; preorbital only slightly more than half the diameter of eye in young (specimen 45 millimeters long), a little broader than eye in adult (specimen 200 millimeters long); mouth moderate, oblique; lower jaw projecting; maxillary partly exposed, reaching about to anterior margin of eye, 2.2 to 3.4 in head; premaxillary process extending to above posterior part of eye; lower lip with its lower margin free throughout; teeth in the jaws all pointed, the anterior pair in upper jaw enlarged, caninelike, the anterior pair in the lower jaw small, with several enlarged teeth on each side; gill rakers short, 7 to 9 more or less developed on the lower limb of the first arch; scales rather large, notably reduced on the chest, extending on base of vertical fins, 5 or 6 rows between origin of dorsal and lateral line, about 8 rows on cheeks; dorsal fin long, the spines graduated, the last one scarcely a third the length of head, the median soft rays produced, reaching opposite middle of caudal in large examples, shorter in young, origin of fin over opercular margin; caudal fin broadly rounded; anal spines strong, the last one a little longer than the last dorsal spine, the soft portion similar to that of the dorsal, origin of fin usually about an eye's diameter nearer base of pectorals than base of caudal; ventral fins inserted a little behind base of pectorals, the exterior ray produced in adult, usually extending to origin of anal; pectoral fins extending scarcely as far back as the ventrals, 1.5 to 1.7 in head.

The color varies with age and also among individuals. A specimen, 260 millimeters in length, when removed from the water, possessed the following coloration: Very dark green above; lower parts of sides lighter; underneath dusky with punctulations; snout brassy; sides with black blotches forming a more or less continuous lateral band; a large black blotch on upper part of opercle; a black caudal spot; sides of head with dark brassy spots; dorsal and anal very dark green with dark spots; caudal somewhat lighter green with dark spots; ventrals dark; pectorals plain brassy. Color of a large specimen, 300 millimeters long, immediately after being removed from the water, bluish silvery on back; lower part of sides pale silvery; belly dingy white; sides with dark blotches forming an interrupted lateral band; body and head, except snout, everywhere with rusty spots; pectorals plain translucent; ventrals dusky; other fins slightly brownish and everywhere with rusty spots, usually surrounded by blue. Young with alternating dark and light cross-bars; the dark lateral band more pronounced than in large examples, except occasionally in the very young (50 millimeters and less in length), in which it is often quite indistinct; these young with a prominent black spot on sides below lateral line at end of pectoral fin and a prominent caudal spot. Most specimens have a dark bar extending from the upper posterior margin of the eye across opercle; not quite connecting with a dark spot just above base of pectoral; another dark bar, frequently consisting of two separate spots, extending from lower posterior margin of eye to lower margin of gill opening.

This rather common lake fish is represented by many specimens, ranging from 25 to 300 millimeters in length. The specimens in hand agree fairly well with published accounts of *C. motaguense,* the types of which are reported from the Rio Motagua, Atlantic slope, Guatemala, and subsequently other specimens were recorded from the "Pacific slope of Central America" from El Rancho, on the Rio Motagua, and from Belize. The El Salvador specimens were taken in lakes and ponds, not a single one having been secured in streams. The apparent difference in habitat between the type specimens of *C. motaguense* and the El Salvador specimens suggests that they may not be identical. In the absence of material for comparison it seems advisable to refer the specimens in the present collection, tentatively at least, to *C. motaguense.*

This is the most common and most important food fish in Lakes Ahuachapan and Coatepeque. In Lake Guija only one specimen was taken, and the species was not seen among the catches of native fishermen. In Lake Chanmico a few small individuals were taken. In three small, spring-fed reservoir ponds at El Angel, situated on private property where the fish are protected, this was the most common species, and the largest individual (330 millimeters in length) seen was taken in one of the ponds.

In Lake Coatepeque this is the only food fish of importance taken. The only other cichlid found there is the small "burro," *C. nigrofasciatum.* The fish in Lake Coatepeque are taken mostly with hook and line and in rather deep water. Several fishermen, during our visit, made fairly good catches fishing at a depth of 25 meters.

This "Guapote" is a good food fish, the flesh being fairly firm and of good flavor. It reaches a larger size than any of the other cichlids, the maximum size attained, according to a local fisherman on Lake Ahuachapan, being about 500 millimeters.

The spawning season and habits are very imperfectly or not at all known. The specimens examined had the sexual organs undeveloped, showing that the spawning season was not near at hand when the specimens were collected (January and February). The food of this fish, according to 6 stomachs examined, in the young consists of entomostracans, insects and other small animal life, and algæ. Larger individuals feed on fish, crustaceans, and probably on plants.

The species is recorded from the Atlantic slope of Guatemala, from British Honduras, and from the "Pacific slope of Central America." The specimens from El Salvador were taken in Lakes Guija, Ahuachapan, Coatepeque, Chanmico, and in small ponds at El Angel.

Order GOBIOIDEA

Family XI. ELEOTRIDÆ

Body elongate, slender or robust; vomerine teeth usually wanting (present in Gobiomorus); premaxillaries protractile; opercle unarmed; orbital margin not free, continuous with skin of head; lateral line wanting; dorsal fins 2; caudal fin convex; ventral fins close together but separate, composed of I, 4 or I, 5 rays.

15. Genus GOBIOMORUS Lacépède

Gobiomorus Lacépède, Hist. Nat. Poiss., II, 1800, 583 (type *Gobiomorus dormitor* Lacépède).
Philypnus Cuvier and Valenciennes, Hist. Nat. Poiss., XII, 1837, 235 (type *Gobiomorus dormitor* Lacépède).
Lembus Günther, Cat. Fish., Brit. Mus., I, 1859, 505 (type *Lembus maculatus* Günther).

Body elongate, anteriorly subcylinderical, posteriorly compressed; mouth large; lower jaw projecting; teeth small, in bands on jaws and on vomer; gill opening large, extending forward to under eye; scales rather small, ctenoid; dorsal fins well separated, with VI–I, 9 rays; anal fin with I, 9 to I, 11 rays. A single species was taken in El Salvador.

22. Gobiomorus maculatus (Günther)

GUVINA

Lembus maculatus Günther, Cat. Fish., Brit. Mus., I, 1859, 505 (Andes of Ecuador).
Philypnus lateralis Gill, Proc., Ac. Nat. Sci., Phila., 1860 (1861), 123 (Cape San Lucas); Jordan and Evermann, Bull., U. S. Nat. Mus., XLVII, 1898, 2195.
Eleotris lembus Günther, Cat. Fish., Brit. Mus., III, 1861, 121 (Western Ecuador).
Gobiomorus lateralis Eigenmann and Fordice, Proc., Ac. Nat. Sci., Phil., 1885 (1886), 69.
Gobiomorus maculatus Eigenmann and Fordice, Proc., Ac. Nat. Sci., Phila., 1885 (1886), 70.
Philypnus maculatus Regan, Biol. Cent. Amer., Pisces, 1906, 5, Pl. I, fig. 2; Meek and Hildebrand, Pub., Field Mus. Nat. Hist., Zoöl. Ser. X, 1916, 352.

Head 3 to 3.4; depth 3.45 to 5.5; D. VI–I, 9; A. I, 10 or 11; scales 55 to 59.

Body elongate, not much deeper than broad anteriorly, compressed posteriorly; caudal peduncle rather strongly compressed, its least depth 2.5 to 3 in head; head long, somewhat depressed; snout long and broad, its length 3.05 to 3.55 in head; eye 4 to 5.2; interorbital 3.6 to 5; mouth large, oblique; lower jaw strongly projecting; maxillary reaching middle of eye, 2.35 to 2.6 in head; teeth small, pointed, in bands on jaws and on vomer; gill rakers minute; lateral line wanting; scales ctenoid, extending forward on head to end of premaxillary processes; origin of spinous dorsal about an eye's diameter behind base of pectorals, the spines weak; origin of soft dorsal about an eye's diameter in advance of anal; caudal fin rounded; anal fin similar to soft dorsal; ventral fins inserted slightly behind base of pectorals, reaching a little more than half the distance to origin of anal; pectoral fins reaching to or a little beyond tips of ventrals, 1.3 to 1.6 in head.

Color of a fresh specimen, 80 millimeters in length, olivaceous, with indefinite and irregular dark markings above; pale underneath; sides with a black lateral band; preopercle with 2 horizontal bands, one extending backward from upper posterior margin of eye, the other a more definite one extending backward from lower posterior margin of eye; a dark band underneath eye; ventral fins pale; other fins greenish; spinous dorsal with black punctulations. In some specimens the dorsal and caudal fins are spotted with dusky markings which are arranged in irregular vertical bars on the caudal.

Several small specimens, ranging in length from 30 to 115 millimeters, were taken in the Rio Lempa. One small specimen was seined at Suchitoto, and all the others were taken at San Marcos, where the species appears to be common in the quiet, shallow, or disconnected pools of the river. No large individuals were seen.

This fish inhabits Pacific-slope streams from Lower California to Peru. The specimens in the present collection are from the Rio Lempa at Suchitoto and San Marcos.

Part II.—ANNOTATED LIST OF MARINE FISHES COLLECTED AT THE PORTS OF TRIUNFO AND CUTUCO, EL SALVADOR

Only part of a day was devoted to collecting at each, Triunfo and Cutuco. Triunfo is situated on a salt-water estuary lying wholly within the Departmento de Usulutan. Cutuco is on Fonseca Bay and is one of the principal ports of El Salvador.

Fish appeared to be rather scarce at both ports during our visit, particularly as to variety. It is only to be expected, of course, that the abundance of fish life varies somewhat with the season. It is probable, however, that fishing is not very profitable, as little of it is being done. So far as known, no regular fisheries, in which modern equipment is used, have been established anywhere along the coast of El Salvador. All fishing observed by the writer was carried on with hook and line and with the cast net, and only very small catches were made. Because of the great scarcity of fresh-water fishes it would be a great help to the Republic if the supply could be more abundantly augmented from the sea. It is entirely possible that this could be done. The duty assigned to us was an investigation of the fresh waters; the two visits to salt water were only incidental, and the time devoted to salt-water collecting and the results obtained are too meager to form the basis for any conclusions. The results obtained, as shown by the following list of species and notes, therefore, should not be interpreted to mean that profitable marine fisheries could not be established. Furthermore, it is not known that fishing with modern gear has been given a trial.

Family CLUPEIDÆ

1. **Opisthonema libertatis** (Günther)

Meletta libertatis Günther, Proc., Zoöl. Soc., London, 1866, 603 (La Libertad).
Clupea libertatis Günther, Cat. Fish. Brit. Mus., VII, 1868, 433.
Opisthonema libertate Jordan and Evermann, Bull., U. S. Nat. Mus., XLVII, 1896, 433; Meek and Hildebrand, Pub., Field Mus. Nat. Hist., Zoöl. Ser., XV, 1923, 188.

Several juveniles were seined at Triunfo. The species is known from Mexico south to Panama Bay.

Family ENGRAULIDÆ

2. **Stolephorus exiguus** (Jordan and Gilbert)

Stolephorus exiguus Jordan and Gilbert, Proc., U. S. Nat. Mus., IV, 1881 (1882), 342 (Mazatlan); Jordan and Evermann, Bull. U. S. Nat. Mus., XLVII, 1896, 442.
Anchovia exigua, Meek and Hildebrand, Pub., Field Mus. Nat. Hist., Zoöl. Ser., XV, 1923, 200.

Many specimens of this species were seined both at Triunfo and Cutuco. The species ranges from Mazatlan to Panama.

3. **Stolephorus panamensis** (Steindachner)

Engraulis panamensis Steindachner (Sitzb. k. Ak. Wiss. Wien., LXXII) Ichth. Beitr., IV, 1875, 39 (Panama).
Stolephorus panamensis Jordan and Evermann, Bull., U. S. Nat. Mus., XLVII, 1896, 448.
Anchovia panamensis Meek and Hildebrand, Pub., Field Mus. Nat. Hist., Zoöl. Ser., XV, 1923, 207, Pl. XV, fig. 1.

A few small specimens were seined at Triunfo.

4. **Stolephorus rastralis** (Gilbert and Pierson)

Stolephorus rastralis Gilbert and Pierson, in Jordan and Evermann, Bull., U. S. Nat. Mus., XLVII, 1898, 2811 (Panama).
Anchovia rastralis Meek and Hildebrand, Pub., Field Mus. Nat. Hist., Zoöl. Ser., XV, 1923, 209.

Many specimens, which appear to belong to this species, were seined at Triunfo. This fish previously was recorded only from Panama.

5. **Stolephorus brevirostris** (Meek and Hildebrand)

Anchovia brevirostra Meek and Hildebrand, Pub., Field Mus. Nat. Hist., Zoöl. Ser., XV, 1923, 198, Pl. XII, fig. 1 (Balboa, Panama).

Two small specimens, which appear to belong to this species, recently described from the Pacific coast of Panama, were seined at Cutuco.

Family ATHERINIDÆ

6. **Thyrinops pachylepis** (Günther)

Atherinichthys pachylepis Günther, Proc., Zoöl. Soc., London, 1864, 25, and Trans., Zoöl. Soc., London, VI, 1868, 443 (Panama).
Menidia pachylepis Jordan and Evermann, Bull., U. S. Nat. Mus., XLVII, 1896, 801.
Thyrina pachylepis Jordan and Evermann, Bull., U. S. Nat. Mus., XLVII, 1898, 2840; Regan, Biol. Cent. Amer., Pisces, 1907, 64.
Kirtlandia pachylepis Gilbert and Starks, Memoir., Calif Ac. Sci., IV, 1904, 57.
Thyrinops pachylepis Hubbs, Proc., Ac. Nat. Sci., Phila., LXIX, 1917 (1918), 307; Jordan and Hubbs, Leland Stanford, Jr., Univ. Pub., Univ. Ser., 1919, 62.

Several specimens of this species were taken in Fonseca Bay at Cutuco. The species has previously not been recorded north of the coast of Costa Rica. The known range now extends from El Salvador to Ecuador.

Family MUGILIDÆ

7. **Mugil curema** (Cuvier and Valenciennes)

LIZA; LIEBRA ANCHA

Mugil curema Cuvier and Valenciennes, Hist. Nat. Poiss., XI, 1836, 87 (Brazil; Martinique ·Cuba); Jordan and Evermann. Bull., U. S. Nat. Mus., XLVII, 1896, 813, Pl. CXXVI, fig. 344; Meek and Hildebrand, Pub., Field Mus. Nat. Hist., Zoöl. Ser., XV, 1923, 279. (For a more complete synonoymy and other references see the two last-mentioned works.)

A few small specimens of this species were taken in salt water at Triunfo.

Family POLYNEMIDÆ

8. **Polynemus approximans** (Lay and Bennett)

Polynemus approximans Lay and Bennett, Zoöl. Beechey's Voyage, Fishes, 1849, 57 (Mazatlan); Meek and Hildebrand, Pub., Field Mus. Nat. Hist., Zoöl. Serv., XV, 1923, 290.
Polydactylus approximans Jordan and Evermann, Bull., U. S. Nat. Mus., XLVII, 1896, 829.

Two small specimens were seined at Cutuco. In some localities this fish is of considerable commercial importance. Its range extends from California to Peru.

Family CARANGIDÆ

9. **Caranx hippos** (Linnæus)

AUREL

Scomber hippos Linnæus, Syst. Nat. Ed., XII, 1766, 494 (Charleston, S. C.).
Caranx hippos Jordan and Evermann, Bull. U. S. Nat. Mus., XLVII, 1896, 920, Pl. CXLI, fig. 387.

Several small specimens of this common and widely distributed food fish were seined at Triunfo and Cutuco. The species is known from the warmer waters of both coasts of America and also from the East Indies.

10. **Oligoplites mundus** (Jordan and Starks)

Oligoplites mundus Jordan and Starks, in Jordan and Evermann, Rept., U. S. Fish Commission, 1896, 344, and Bull., U. S. Nat. Mus., XLVII, 1898, 2844 (Mazatlan).

A single small specimen was seined at Triunfo. The species ranges from the Gulf of California to Ecuador.

11. **Oligoplites saurus** (Bloch and Schneider)

Scomber saurus Bloch and Schneider, Syst. Ichth., 1801, 321 (Jamaica).
Oligoplites saurus Jordan and Evermann, Bull., U. S. Nat. Mus., XLVII, 1896, 898.

Three small specimens were seined at Triunfo. The species is of no commercial value. It occurs on both coasts of tropical America.

Family CENTROPOMIDÆ

12. **Centropomus pectinatus** (Poey)

ROBALO; ROVALO

Centropomus unidecimalis Cuvier and Valenciennes (part), Hist. Nat. Poiss., II, 1828, 102.
Centropomus pectinatus Poey, Memorias, II, 1860, 121 (Cuba); Jordan and Evermann, Bull., U. S. Nat. Mus., XLVII, 1896, 1122.

Two specimens, respectively 220 and 280 millimeters in length, were taken at Triunfo. A large specimen, 350 millimeters long, was taken in fresh water in the Rio Lempa at San Marcos.

13. **Centropomus robalito** (Jordan and Gilbert)

ROBALO; ROVALO

Centropomus armatus Günther (not Gill), Trans., Zoöl. Soc., London, 1868, 408.
Centropomus robalito Jordan and Gilbert, Proc., U. S. Nat. Mus., IV, 1881 (1882), 462 (Mazatlan; Acapulco); Jordan and Evermann, Bull., U. S. Nat. Mus., XLVII, 1896, 1123.

A single small specimen was secured at Triunfo and several others in fresh water in the Rio Lempa at San Marcos.

Family EPINEPHELIDÆ

14. **Epinephelus analogus** (Gill)

PARGO TIGRE

Epinephelus analogus Gill, Proc., Ac. Nat. Sci., Phila., 1864, 163 (Panama); Jordan and Evermann, Bull., U. S. Nat. Mus., XLVII, 1898, 1152.
Serranus courtadii Bocourt, Ann. Sci. Nat., Paris, 1868, 222 (La Union, San Salvador).

A single specimen, 235 millimeters in length, was taken at Cutuco. The range of the species extends from Mexico to Panama and the Galapagos and Revillagigedo Islands.

Family LUTIANIDÆ

15. **Lutianus argentiventris** (Peters)

PARGO; PARVO

Mesoprion argentiventris Peters, Berlin. Monatsber., 1869, 704 (Mazatlan).
Neomænis argentiventris Jordan and Evermann, Bull., U. S. Nat. Mus., XLVII, 1898, 1260.

Several individuals of this species were killed with dynamite in the estuary at Triunfo, where this snapper appears to be common. It was not seen in fresh water. The species is known from Lower California to Ecuador.

16. **Lutianus novemfasciatus** (Gill)

PARGO; PARVO

Lutianus novemfasciatus Gill, Proc., Ac. Nat. Sci., Phila., 1862, (1863), 251 (Cape San Lucas).
Neomaenis novemfasciatus Jordan and Evermann, Bull., U. S. Nat. Mus., XLVII, 1898, 1252.

Many individuals of this species were killed with dynamite in the estuary at Triunfo. One large individual, 475 millimeters in length, which could not at the time be preserved, was taken in the same way in strictly fresh water in the Rio Lempa at San Marcos. Measurements, counts, and a color description were made in the field, and it is believed that this fish belonged to the present species. This snapper appears to be one of the most plentiful food fishes in the estuary at Triunfo. The species ranges from Lower California to Colombia.

Family POMADASIDÆ

17. **Orthopristis chalceus** (Günther)

RONCAN

Pristipoma chalceum Günther, Proc., Zoöl. Soc., London, 1864, 146, and Trans., Zoöl. Soc., London, VI, 1868, 415 (Panama Bay).
Pristipoma kneri Steindachner (Sitzb. k. Ak. Wiss. Wien, LX) Ichth. Notiz., VIII, 1869, 3, Pl. II (Mazatlan).
Pristipoma chalceus Jordan and Evermann, Bull., U. S. Nat. Mus., XLVII, 1898, 1337.

A single specimen, 185 millimeters in length, was secured at Triunfo. This is an important food fish in some sections on the Pacific coast of Central America. Its range extends from Lower California to Panama and the Galapagos Islands.

18. **Pomadasis panamensis** (Steindachner)

Pristipoma panamense Steindachner (Sitzb. k. Ak. Wiss. Wien., LXXII) Ichth. Beit., III, 1875, 8, Pl. I, fig. 1 (Panama Bay).
Pomadasis panamensis Jordan and Evermann, Bull., U. S. Nat. Mus., XLVII, 1898, 1331.

A single specimen, 170 millimeters long, was secured at Triunfo. Most of the representatives of this genus frequent fresh water, but it is not known that the present species enters streams. The species ranges from Guaymas to Panama.

19. **Anisotremus dovii** (Günther)

Bernegate

Pristipoma dovii Günther, Proc., Zoöl, Soc., London, 1864, 23, Pl. III, fig. 1, and Trans., Zoöl. Soc., London, VI, 1868, 414 (Panama).
Anisotremus dovii Jordan and Evermann, Bull., U. S. Nat. Mus., XLVII, 1898, 1317.

A single specimen, 165 millimeters in length, was taken at Cutuco. It was the only one among a dozen of its nearest relative, *A. pacifici.* The species ranges from Mazatlan to Panama.

20. **Anisotremus pacifici** (Günther)

Bernegate

Conodon pacifici Günther, Proc., Zoöl. Soc., London, 1864, 147, and Trans. Zool. Soc., London, VI, 1868, 417, Pl. LXIV, fig. 3 ("Chiapam," Pacific coast of Guatemala).
Anisotremus pacifici Jordan and Evermann, Bull., U. S. Nat. Mus. XLVII, 1898, 1316.

Several specimens of this species were seen at Triunfo and Cutuco, and three were preserved. It appears to be among the common food fishes in Fonseca Bay. The range of this species extends from Guatemala to Guayaquil.

Family GERRIDÆ

21. **Gerres peruvianus** Cuvier and Valenciennes

Mojarra

Gerres peruvianus Cuvier and Valenciennes, Hist. Nat. Poiss., VI, 1830, 467 (Payta, Northern Peru); Jordan and Evermann Bull., U. S. Nat. Mus., XLVII, 1898, 1376.

Several small specimens were seined at Triunfo, where the species appears to be common. Its range extends from Mazatlan to northern Peru.

Family EPHIPPIDÆ

22. **Chætodipterus zonatus** (Gerard)

Chopa

Ephippus zonatus Girard, Exp. Surv. R. R. Route, Miss. R. to Pac. Ocean, 1858, 110 (San Diego, Calif.).
Chætodipterus zonatus Jordan and Evermann, Bull., U. S. Nat. Mus., XLVII, 1898, 1668.

A single specimen, 270 millimeters in length, was taken at Triunfo. The species ranges from California to Ecuador.

Family GOBIIDÆ

23. **Gobionellus sagittula** (Günther)

Euctenogobius sagittula Günther, Proc., Zoöl. Soc., London, 1861, 3 (west coast of Central America).
Gobius longicaudus Jenkins and Evermann, Proc., U. S. Nat. Mus., XI, 1888, (1889), 146 (Guaymas).
Gobionellus sagittula Jordan and Evermann, Bull., U. S. Nat. Mus., XLVII, 1898, 2228; Gilbert and Starks, Memoir., Cal. Ac. Sci., IV, 1904, 171.

Seven fine specimens, ranging in length from 32 to 78 millimeters, were seined in the estuary at Triunfo. The species ranges from the Gulf of California southward to Ecuador.

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FUR-SEAL INDUSTRY OF THE COMMANDER ISLANDS, 1897 TO 1922

⁂

By LEONHARD STEJNEGER

Head Curator of Biology, United States National Museum

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INTRODUCTION

In the spring of 1882 Prof. Spencer F. Baird, secretary of the Smithsonian Institution and United States Commissioner of Fish and Fisheries, sent the writer to the Commander Islands, in the North Pacific Ocean off the coast of Kamchatka, for the purpose of collecting specimens for the United States National Museum and to investigate the natural history of the islands in general. Bering and Copper Islands were visited from May, 1882, to September, 1883, and it was thus possible, during two full seasons, to study the fur seals and the fur-seal industry of these islands and their distribution and to make maps and sketches of the seal rookeries. At that time pelagic sealing had not yet begun and the Commander Islands, which belong to Russia, were at the zenith of their productivity, the take of sealskins during the years 1880 to 1889 averaging 44,363 per year. The insight into the fur-seal industry thus gained during its most prosperous period was of great value later. With the year 1892 began the terrible onslaught of pelagic sealers on the seal herd of the Commander Islands, which resulted in an average loss of about 100,000 seals a year in excess of the normal mortality of the herd.

In 1895 the United States Fish Commission, wishing to obtain reliable information as to the status of the fur-seal industry in the North Pacific, commissioned Dr. F. W. True and the writer to proceed to the seal islands, Doctor True to report on the Pribilof Islands while to this author was allotted the investigation of the Commander Islands. The stay on the Commander Islands lasted from July 3 to September 16, during which time all the rookeries were thoroughly investigated, photographed, and mapped. As a result of this trip there was published in the bulletin of the United States Fish Commission (Vol. XVI, 1896) the writer's report on The Russian Fur-Seal Islands [1] (148 pp. and 66 pls., including maps of both islands and every rookery, showing the distribution of the seals in 1883 and 1895).

As a member of the Commission on Fur-Seal Investigations appointed by President Cleveland in 1896 to act in conjunction with commissioners appointed by Great Britain and Canada with special reference to the effect of the regulations made by the Paris Arbitration Tribunal for the protection of the seal herd, the writer again visited the Pribilof Islands, spending 10 days there. The Commander Islands were next visited, and the rookeries on both islands were inspected and photographed between July 30 and August 8, after which the writer proceeded to the Kuril Islands belonging to Japan. On August 29 and 31 the then Russian seal rookery, Robben Island, in the Okhotsk Sea off the east coast of Sakhalin, was inspected, photographed, and mapped. During the summer of 1896, therefore, practically all of the fur-seal rookeries of the North Pacific, Bering Sea, and Okhotsk Sea were inspected.

In 1897 the writer again inspected the Russian islands. The entire sealing season, from July 7 to September 2, was spent on Copper Island and Bering Island studying the various problems with special reference to the effect of pelagic sealing on the greatly reduced Russian herd.

During five sealing seasons on the Commander Islands it has thus been possible for the writer to gain an intimate knowledge of the fur-seal question, not only during the period of greatest expansion but also during the period of greatest decline due to the nefarious practice of pelagic slaughter by foreign sealers.

The final report on this work was published in volume 4 of the large Report of the Fur-Seal Investigations, 1896–97, as Part IV of The Fur Seals and Fur-Seal Islands of the North Pacific by David Starr Jordan and associates, under the title The Asiatic Fur-Seal Islands and Fur-Seal Industry (1898, 384 pp., 113 pls., including diagrams and maps). In this report, which will be referred to hereafter merely as The Asiatic Fur-Seal Islands, a detailed description is given of the islands, the flora and fauna, the inhabitants, the fur-seal industry and its history on the Russian islands from their first discovery in 1741 to and including 1897, accompanied by photographs and maps of all the rookeries showing the distribution of the seals in 1882–83 and 1895–1897. The report also includes a full account of the Japanese fur-seal islands and pelagic sealing on the Japanese and Russian coasts.

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[1] This report was reprinted in Alaska Industries, House Document No. 92, part 4, 1898, pp. 613–754, pls. 1–67.

The investigations of the commission indisputably demonstrated the fact that the disastrous decline of the various seal herds was due to pelagic sealing alone. It was made equally evident that the measures of protection devised by the Paris tribunal for the conservation of the seals were utterly inadequate and that if relief were not afforded soon the seal herds would eventually be destroyed commercially. The regulations made by the Paris tribunal legalized pelagic sealing during the migrations of the seals in the Pacific Ocean south of Bering Sea. The American side of the latter was closed to all pelagic sealing until August 1, after which date it was permitted up to within 60 miles of the Pribilof Islands, it being supposed that this time limit and zone sufficed for the protection of the female seals during the breeding season. It should be noted that the regulations of the Paris tribunal related only to the Pribilofs, the American islands, and not to the Russian or Commander Islands, over which the tribunal had no jurisdiction. Russia, in the meantime, negotiated a separate treaty with Great Britain for the protection of the herd of the Commander Islands; but illusory as was the American protection, that devised for the Russian islands was even worse, for the protecting zone was fixed at 30 miles around the Commander Islands with no restrictive time limit during the breeding season.

In the meantime the annual yield from the killing of bachelor seals on land and breeding females at sea was gradually dwindling, and a flourishing industry, the income from which had more than reimbursed the United States for the entire original purchase price of Alaska, was threatened with extinction when the Governments of the United States, Great Britain, Russia, and Japan finally realized that something had to be done. The negotiations that followed resulted in the abolition of legal pelagic sealing by the nationals of the four powers in the North Pacific and adjacent seas, a convention to that effect being concluded in Washington on July 7, 1911.

The beneficial effect of this treaty became apparent almost immediately on the Pribilof Islands. Despite the cessation of commercial land killing for five years, which retarded the rehabilitation of the herd, the number of seals increased from about 216,000 in 1912 to approximately 605,000 in 1922. Returns from the Japanese Government of the 10 per cent of the skins taken on Robben Island indicated similarly improved conditions there. Only from the Russian islands no authentic information was forthcoming. The question as to whether this lack of information was due solely to the distracted condition of the Far East after the Russian revolution or whether other circumstances were responsible naturally arose, in view of the fact that the treaty of July 7, 1911, was to continue in force for a period of 15 years from December 15, 1911, and thereafter until terminated by 12 months' written notice, which notice might be given at the expiration of 14 years—consequently on or after December 15, 1925. Early in 1922, therefore, the Department of Commerce decided to make an investigation of conditions existing there.

Because of the writer's previous experience in fur-seal matters in Asiatic waters he was detailed by the United States National Museum to conduct the investigation for the Department of Commerce, and had to aid him Capt. Carl E. Lindquist, of Oakland, Calif., whose 14 years of service on various vessels in Asiatic waters and familiarity with sealing conditions made his assistance invaluable.

The writer wishes to express his thanks to Mr. Henry O'Malley, Commissioner of Fisheries, who made possible this visit to the Commander Islands, and who placed at our disposal every facility for visiting the various rookeries and for studying the fur-seal question from all angles, as well as securing for our assistance the services of Capt. C. E. Lindquist. To my old friend Captain Lindquist I also express my appreciation and thanks, and I gratefully acknowledge the help and courtesies received from all members of the crews of the Coast Guard cutters *Mojave* and *Algonquin*, on which transportation was had to and from the islands, and particularly from Ward T. Bower, of the Bureau of Fisheries, who contributed so much to the success of the investigation.

INVESTIGATION OF THE COMMANDER ISLANDS IN 1922

ITINERARY

According to the original plan the investigation was to have continued for about one month, but because of bad weather, delays in transportation, etc., only 16 days in all were spent on the islands, during most of which time conditions were unfavorable for photographing and inspecting the rookeries.

The first place visited was Glinka, the southern rookery village of Copper Island, which was reached on July 24, 1922, on the Coast Guard cutter *Algonquin*. No officials were located at the village, only a rookery guard of 10 natives. These we interrogated as to the condition of the Glinka rookeries, intimating that it was desired to inspect them, but the guards were unwilling to allow this without a permit from the fisheries official located at the main village. We therefore proceeded to that point and received permission to go ashore from the government manager of the fur industry of the islands. There being no sealing, all the inhabitants were assembled in the village and we were met with the greatest hospitality and good will. The condition of the natives was better than we had anticipated, though we found them lacking in good clothing, especially shoes, and also in certain provisions.

The authority recognized by the officials and inhabitants was that of the Merkulof government at Vladivostok and of the governor of the Kamchatka district, and the old white-blue-red flag of Imperial Russia was displayed at the signal bluff above the village. We were told that a number of Japanese seal poachers were being held in custody, having been taken prisoner the day before, and their schooner, which had been seized, was seen lying at anchor in the little cove of the village.

As the weather absolutely prevented any rookery work on Copper Island we decided to proceed as soon as possible to Bering Island. The island manager accompanied us in order to authorize our stay at that island, and toward evening on July 26 we landed at Nikolski, the main village.

On July 28 North Rookery was inspected and, as far as the rain and gale would allow, photographed. The weather continued rainy with heavy fog until August 1, but the time was not entirely lost as the writer was given free access to the official archives from the records of which valuable extracts were made relating to the fur-seal industry of the islands during the 25 years since our last visit.

The fog continued to hang so low over the island that it was impossible to make further observations on the rookeries, and on August 8 we departed on the Coast Guard cutter *Mojave.* Robben Island, in the Okhotsk Sea, was visited on August 11, and on August 20 we arrived at Hakodate, where the firm that had entered into a contract with the Vladivostok government for the handling of the Commander Islands furs for the next three years and the provisioning of the inhabitants was interviewed.

On August 30 a brief interview was had at Tokyo with the fur expert who visited the Commander Islands in 1915 and 1916 and inspected the seal rookeries there, and in Yokohama much valuable information was obtained from a former administrator of the Commander Islands, who served from 1907 to 1917.

THE RUSSIAN FUR-SEAL ISLANDS

In 1898 the fur-seal islands still belonging to the Russian Crown consisted of the Commander Islands, located off Kamchatka between the Pacific Ocean and Bering Sea, and Robben Island in the Okhotsk Sea. The latter island was ceded to Japan in the treaty of peace following the Russo-Japanese War of 1904–5. There remain, therefore, in Russian possession at the present date only the Commander Islands.

CONDITION OF THE COMMANDER ISLANDS IN 1922

The Commander or Komandorski Islands, so named after Commander Bering, who discovered the group in 1741, comprise two main islands—Bering and Copper (Miedni)—situated off the east coast of Kamchatka between 54° 33′ and 55° 22′ north latitude and 165° 40′ and 168° 9′ east longitude, about 750 miles west of the Pribilof Islands. Bering Island is about 50 miles long by an average of 10 miles wide, and Copper Island 30 miles long by 2 miles wide on the average. Both islands are very mountainous, the altitude of the highest peak on Bering Island, Mount Steller, being given as 670 meters[2] (2,198 feet), and that on Copper Island, Mount Stejneger, as 637 meters[3] (2,090 feet).

BERING ISLAND

During my former visits the seals on Bering Island were distributed between two rookeries—great North Rookery, situated on the northernmost prolongation of the island (Severni Mys or Cape Yushin), and South Rookery, situated about midway on the western coast of the island—but the latter rookery is now extinct.

Reef, North Rookery, in 1922.—This rookery was formerly the largest and most important on the Commander Islands and has, perhaps, received the greatest attention. The inspection in 1922 took place on July 28.

Upon arrival at the rookery great changes from former days were noticed. Several of the old buildings were missing, among them the small house of the sealer near the salt house, as well as the house marked on the 1895 map as the "cossack's house." Nearly every trace of the "abandoned village" of the same map had disappeared, and many of the sod huts of the "new village" were in ruins. In their place a large frame house had been erected by the Government just back of the old village for occupancy by the overseer and other officials, evidently built at a time when the rookery was in a more flourishing condition but now plainly showing evidence of decay. As no sealing was going on at this season, the native population was congregated at the Saranna village, nearly 7 miles farther east, busy with catching and drying salmon for winter food, and only a guard of a dozen young men was located at the rookery village. The salt house, which contained nothing but a small quantity of old and discolored salt, was in a very dilapidated condition. The floor was covered with mold and slime and had rotted away in places; the roof was leaking badly.

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[2] Fedtschenko, Boris: Flore des îles du Commandeur, 1906, p. 1. Cracovie.

[3] Morozewicz, J.: Mémoires du Comité Géologique (N. S.), Pt. 72, 1912, p. 45.

The decay of the buildings was as nothing, however, compared with the desolation presented to view from the salt-house platform overlooking the rookery, from which the writer's first sketch of the teeming masses of seals was made just 40 years before (July 30, 1882; see plate 20, Asiatic Fur-Seal Islands). At first only a few straggling bulls could be discovered on the main rookery and a handful of seals on the Sivutchi Rocks. Presently, as the overseer pointed them out, a thin line of seals was observed above the grass to the left. In the beginning some difficulty was experienced in becoming oriented, as the first things looked for were the white "sands" and "parade grounds," where the breeding harems used to be lying in thick masses with the characteristic black "band" of seals obliquely across the sandy, gently rounded peninsula (fig. 1). To the writer's astonishment it became apparent that this entire space, except a very narrow fringe of whitish sand along the northern edge, was overgrown with a tall, dense growth of coarse grass (Elymus), and that not only was this grand rookery depleted almost beyond belief, but it must have been so for a considerable period for this gravelly surface to have become so densely overgrown with vegetation.

We descended on the rookery. It was low tide, and we walked out to the large rocks directly north of the peninsula without seeing a cow or pup seal, over ground where formerly thousands of seals bred and where it would have been impossible to have walked except in the spring before the seals had arrived or during the sealing season when taking part in a drive. Occasionally a roaming bull or half bull, of which there seemed to be a great superfluity, would amble across our path apparently in search of cows. By this time the wind had increased almost to a gale so that it was impossible to set up a tripod and camera, and a few instantaneous exposures with the small kodak were the only photographs that could be secured. The extent of the arc covered by the seals was sketched in on the map (fig. 8)[4] and an attempt was then made to estimate the number of seals present on the rookery.

The first location of our observation point being found very unsatisfactory (fig. 3)[5], we proceeded cautiously to the western edge of the reef and there gained a somewhat better view (fig. 4). An attempt was then made to count the bulls, at least, but the count was quite illusory. It is certain that among the females there were many bulls which we could not and did not see. At a rough estimate, based on the various "counts" by the writer, Captain Lindquist, Mr.

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[4] The accuracy of this has since been verified from the photographs.

[5] This was chiefly because only a few seals could be seen. For comparison with conditions in 1895 and 1897 photographs from nearly the same standpoint are added (figs. 5 and 6).

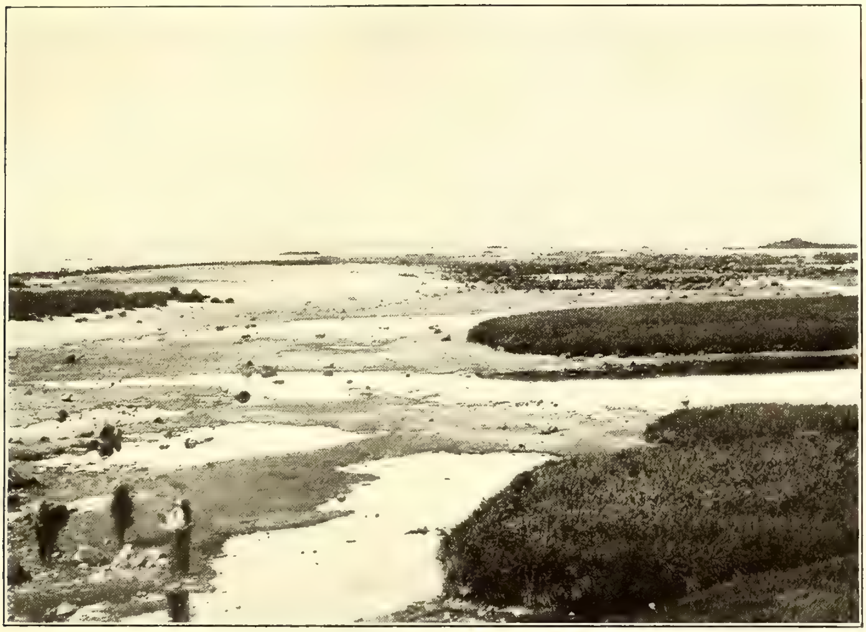

FIG. 1.—North Rookery, Bering Island, July 13, 1897, 1.30 p. m., from driveway. Sunshine

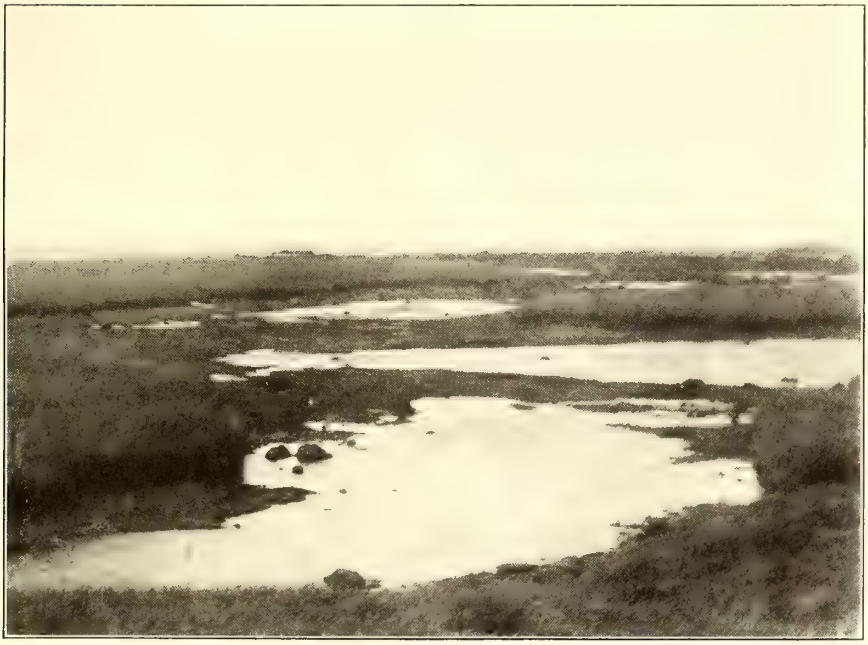

FIG. 2.—North Rookery, Bering Island, July 28, 1922, 1.30 p. m., from same standpoint as above Rain

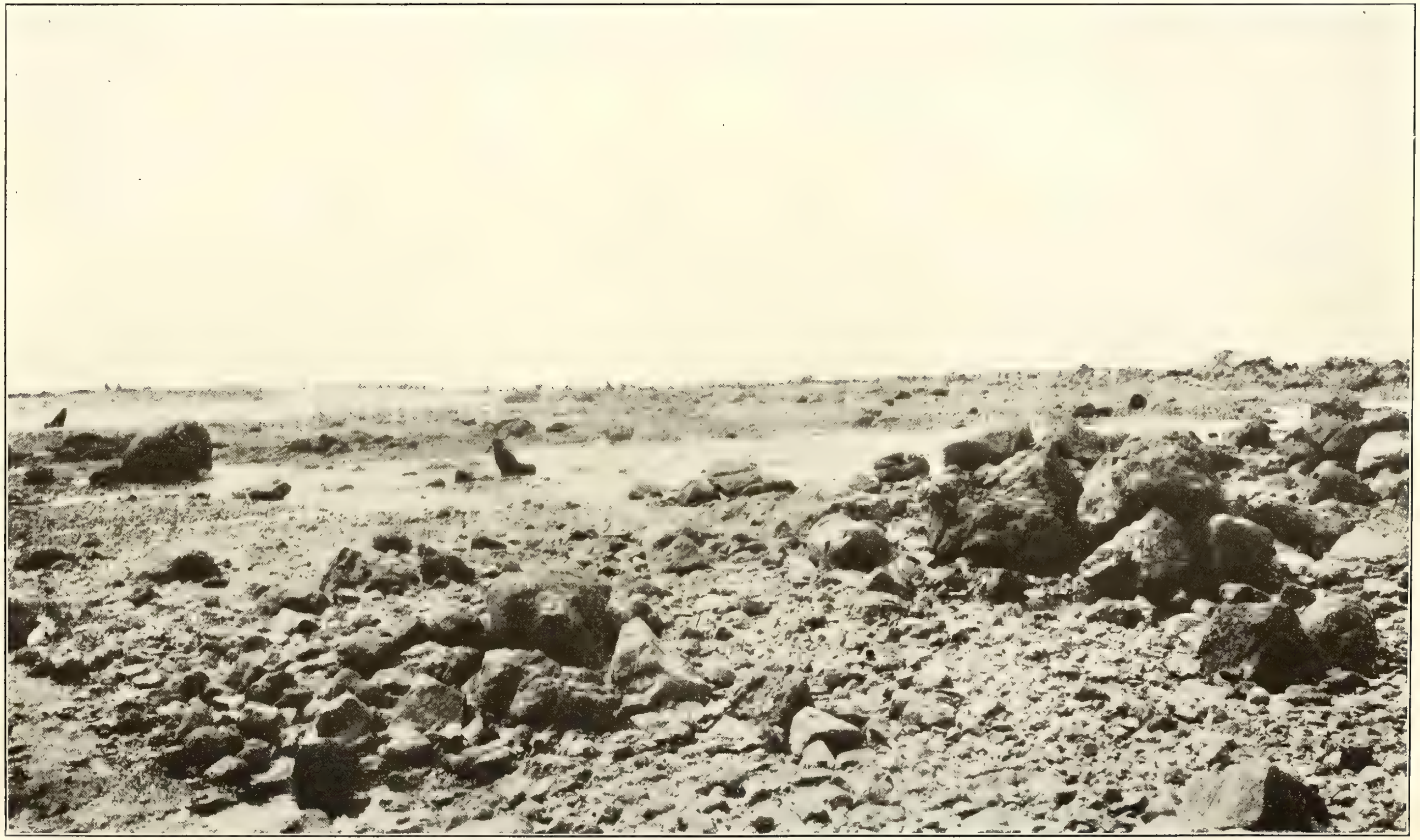

FIG. 3.—North Rookery, Bering Island, July 28, 1922, 12.30 p. m. From photo station No. 1 shown in Figure 7. Cloudy

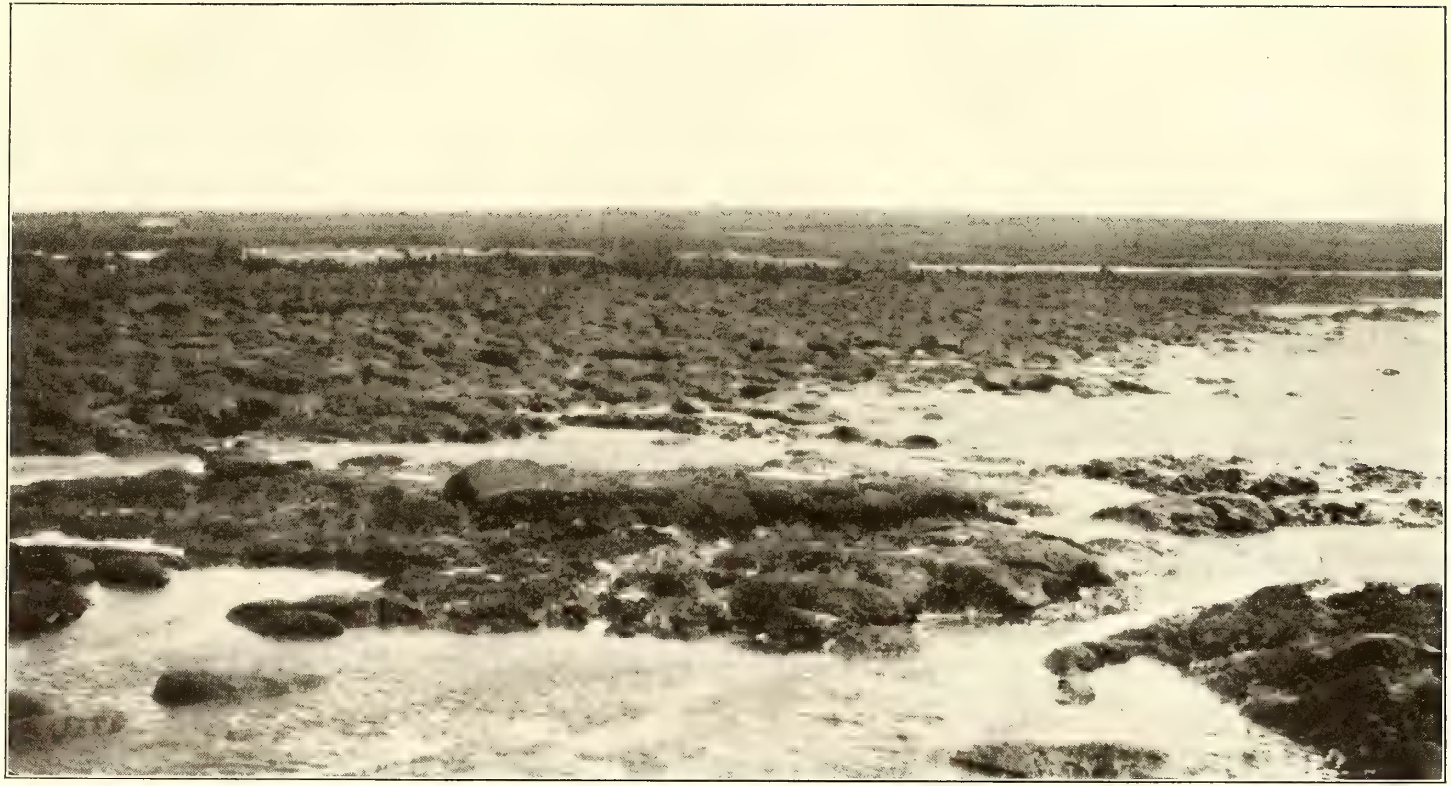

Fig. 4.—North Rookery, Bering Island, July 28, 1922, 1 p. m. From photo station No. 2 shown in Figure 7. Rain

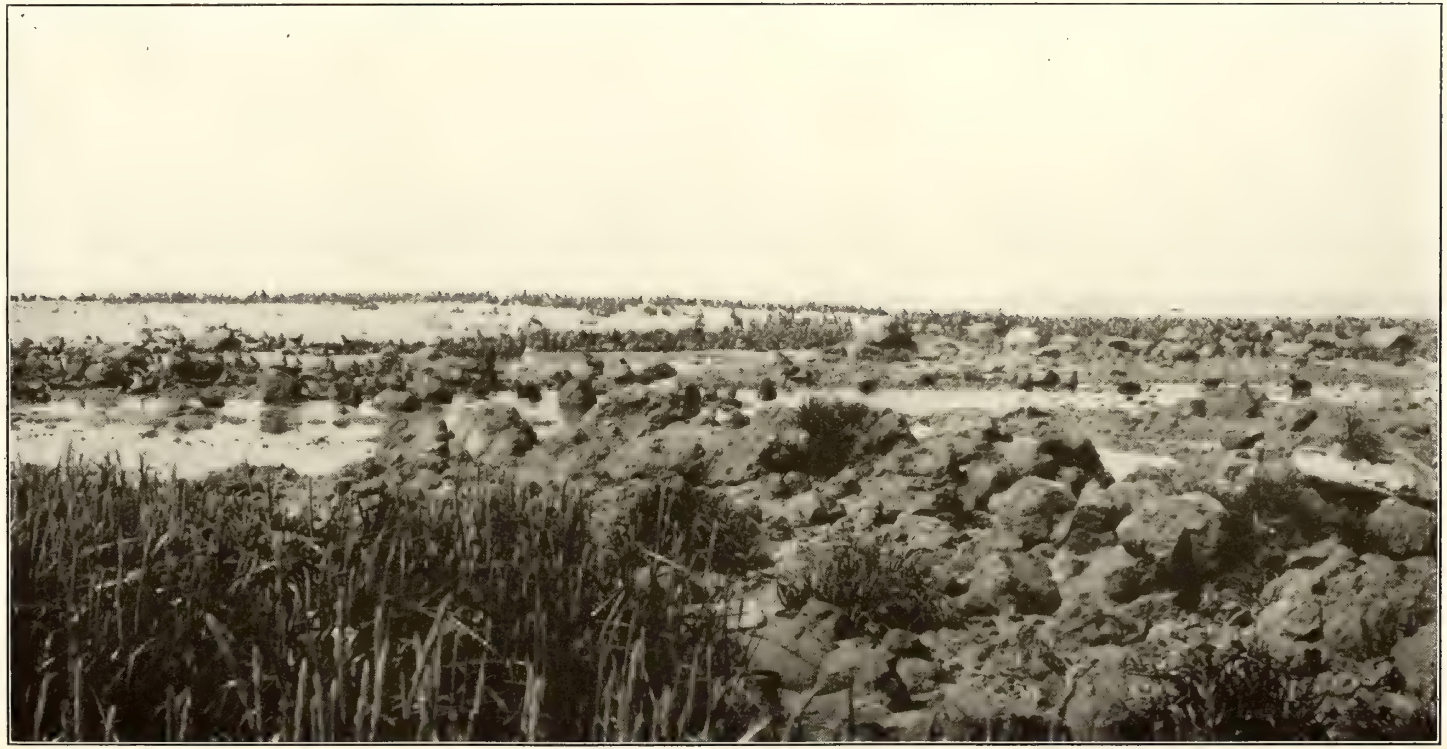

FIG. 5.—Part of North Rookery, Bering Island, July 13, 1897, 1 p. m. From nearly the same standpoint as Figure 3

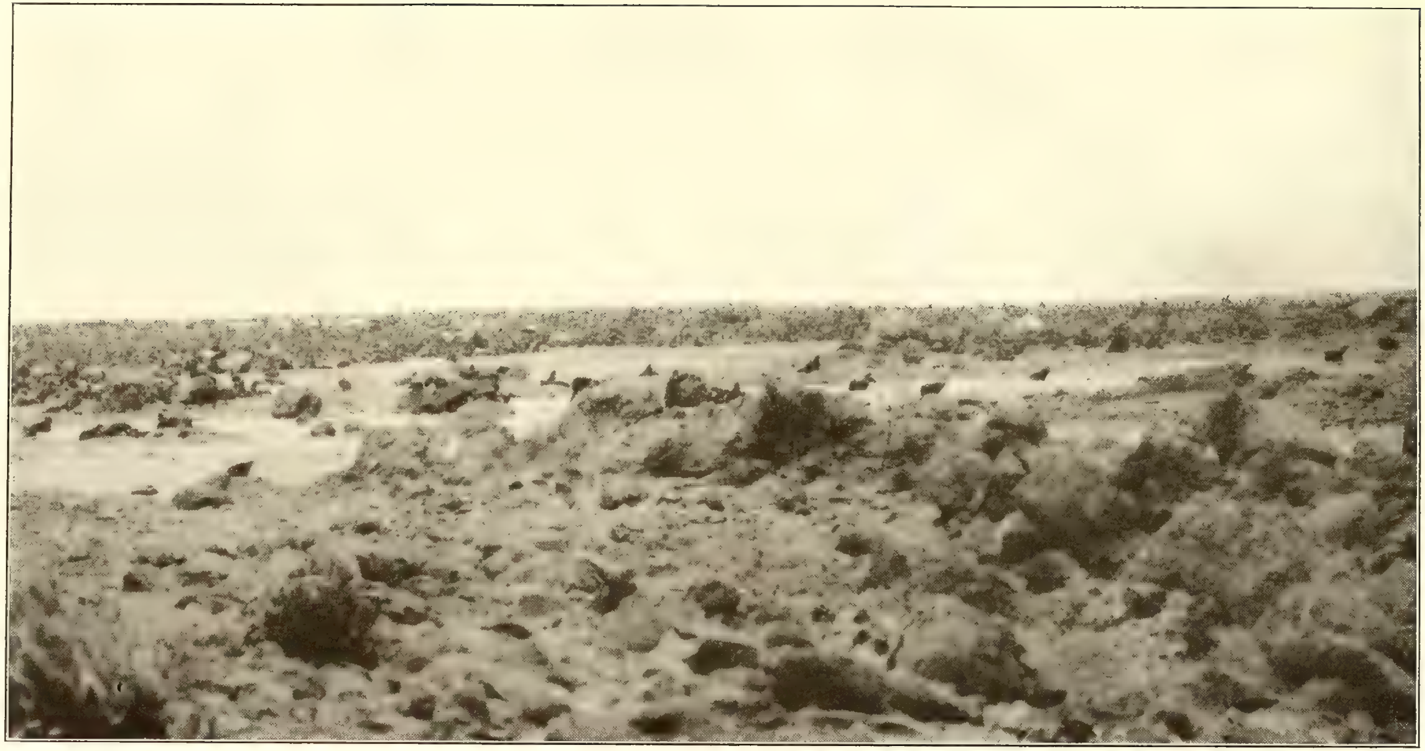

Fig. 6.—Part of North Rookery, Bering Island, 1895 From same standpoint as Figure 5

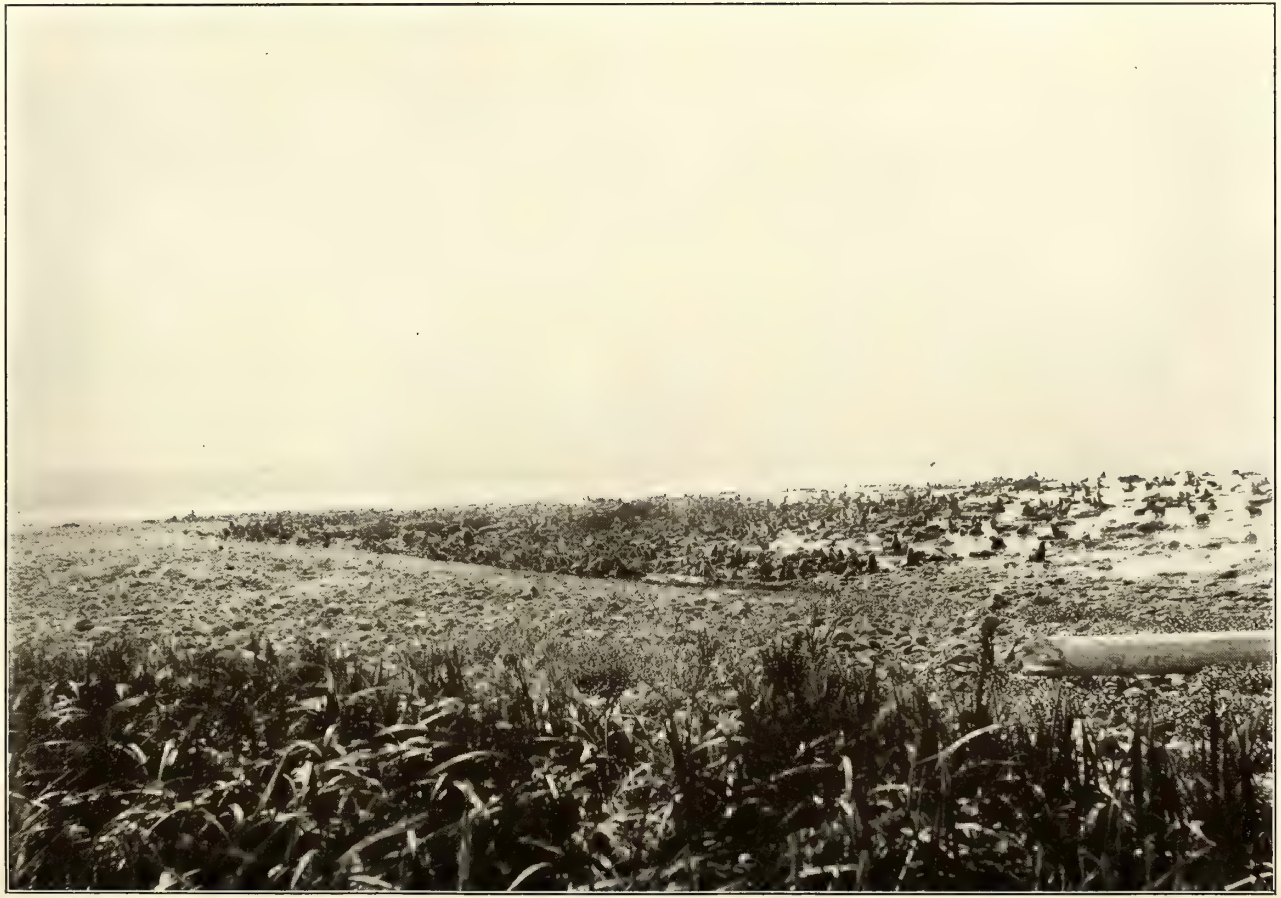

Fig. 7.—Kishotchnoye Rookery, Bering Island, July 13, 1897, 2 p. m. Northern third from north end of rookery

Pyeshkof, and the native overseer, about 100 bulls, "idle" or otherwise, were actually seen, but it would not be surprising if there were as many more lying down among the females or hidden behind rocks which escaped our observation. After a reconsideration of all the various factors involved, we reaffirm our first impression that the total number of seals, exclusive of pups, on North Rookery on July 28, 1922, did not equal the rough count of seals on Kishotchnoye Rookery on July 16, 1897, viz, 3,000 (Asiatic Fur-Seal Islands, p. 166). The seals were lying in a comparatively thin belt along the western edge of the Reef proper, from the extreme northern point of the "peninsula" halfway down toward the large rock marked on the map as Babin. In addition, two harems were seen on the outlying rock known as Little (Mali) Sivutchi Kamen, while a few others, probably less than a dozen, were located on the outer or northern side of Sivutchi Kamen itself (fig. 8).

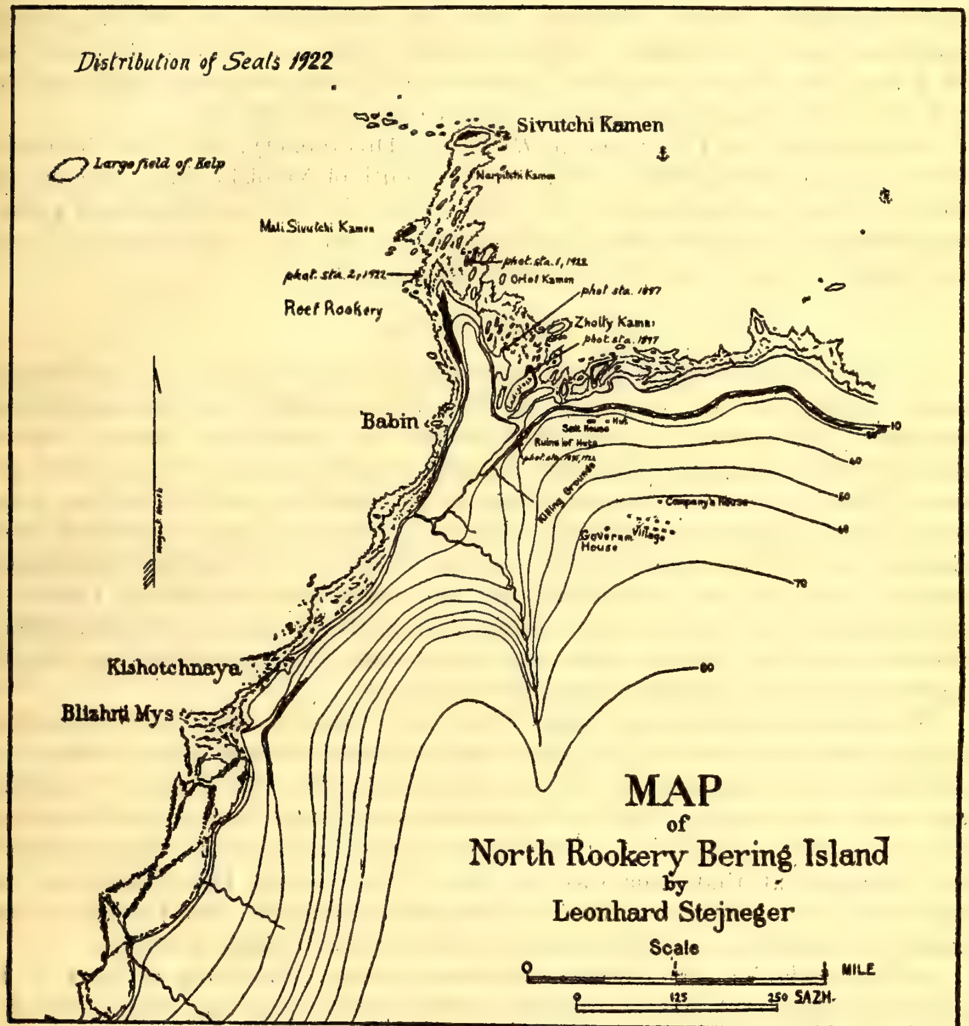
Distribution of Seals 1922
Large field of Kelp
Sivutchi Kamen
Narpitchi Kamen
Mali Sivutchi Kamen
phot. sta. 1, 1922
phot. sta. 2, 1922
Orlof Kamen
phot sta. 1897
Reef Rookery
Zholty Kamen
phot. sta. 1897
Babin
Salt House
Hut
Ruins of Huts
Killing Grounds
Company's House
Governm. House
Village
10
40
50
60
70
80
Kishotchnaya
Blizhni Mys
MAP
of
North Rookery Bering Island
by
Leonhard Stejneger
Scale
0
MILE
125
250 SAZH.

FIG. 8.—North Rookery, Bering Island, showing distribution of seals July 28, 1922, according to Stejneger

Returning from the rookery a final attempt was made to take a photograph from the identical station and with the same lens employed in 1897, but owing to the fierce wind and the rain the plate shows nothing beyond the fact that the grass now extends over the entire area formerly showing up white—the "sands" and "parade grounds" (fig. 2).

Kishotchnoye Rookery.—The chapter relating to the fur seals on this and many other Commander Islands rookeries must now necessarily read like the famous chapter on reptiles in Iceland: There are none. Even as late as 1910 there were still a few seals left on this beach, which in 1882 was continuous with the Reef Rookery, but the seals have long since left it completely (fig. 8).

South Rookery or Poludionnoye Rookery.—This rookery, which was located on the west coast of Bering Island about 20 miles south of Nikolski village, is long since extinct, as was to be expected. In 1897, when the seals on that small rookery were counted, there were only 2 able-bodied harem bulls and about 526 cows. The rookery, as such, ceased to exist shortly thereafter.

COPPER ISLAND

A visit to the Copper Island rookeries was prevented by the unfavorable weather conditions, the shortness of the time available, and the lack of transportation. The account given the writer by the overseer at Glinka, however, was sufficiently detailed to present a fairly reliable picture of the actual situation. What was said of the conditions there seemed to us, who had not visited the rookeries in question since 1897, almost incredible in spite of our faith in the reliability of our informant, but his account received a startling confirmation when we witnessed the destruction that had taken place on Bering Island. It was a shock to learn that the big complex of rookeries known as the Karabelnoye Rookeries had been totally wiped out, not a single seal remaining, and that the Karabelnoye village had been abandoned years ago.

The fur-seal rookeries on Copper Island were formerly distributed in two large groups on the west coast of the island with the corresponding sealing villages and salt houses on the opposite side, viz, a northern group (Karabelni) about 8½ nautical miles south of the main village (Preobrazhenskoye), and Glinka, about the same distance farther south, near the southeastern end of the island. The capacity of these rookeries at that time was in excess of the Bering Island rookeries, and Karabelni's was slightly less than one-half that of Glinka. For the sake of uniformity the scant data available are given under their separate headings.

Glinka rookeries.—The Glinka rookeries consist of a string of more or less isolated beaches, each with a distinct rookery name, spreading over a stretch of coast approximately 5 statute miles long. From north to south the principal features are named as follows: Lebiazhe, Urili, Zapadnoye, Sabatcha Dira, Palata, Zapalata, Sikatchinskoye (Vodopad), Gavarushetche, and Babitche. In 1897 the first and the last were inhabited by bachelors only, and the others ranked in importance in the following order: Palata, Urili, Zapalata, Zapadnoye, Sikatchinskoye, Gavarushetche, and Sabatcha Dira. In 1910, according to Suvorof, the sequence was: Zapalata, Urili, Lebiazhe, Zapadnoye, Sikatchinskoye, Palata, Babitche, and Gavarushetche, while Sabatcha Dira had disappeared as a rookery.

In 1922 the seals had practically disappeared south of Palata. Where 25 years ago they were in evidence at Sikatchinskaya and other places, as shown by Figure 9, now there was none. Palata itself, one of the grandest views on the island[6] (Plate 72, Asiatic Fur-Seal Islands), had shrunk to a handful of seals. Khabarof mentioned 25 big bulls and about 35 cows. Zapadnoye also had vanished, but Urili and Lebiazhe were still holding their own; that is, in comparison with the last 10 years or more.

Karabelnoye Rookeries.—The rookeries opposite Karabelnoye village were more contiguous than those at Glinka (see Plate 99, Asiatic Fur-Seal Islands) and extended not more than about 1½ statute miles along the coast. Most of the coves under the overhanging cliffs were difficult of access from the land side and individually less significant than the Glinka rookeries, hence they have always been treated of as a whole and no estimate made of the seals occupying each cove or rock. In 1896 I thought there were still 10,000 breeding seals present on those beaches. In 1910 there were still some left at Nerpitcha Bukhta (or Nerpitchi Kamen), for Suvorof estimated the number present at 3 bulls and 150 cows. In 1911 the last seal disappeared, and in 1922 Karabelnoye rookery was ancient history.

NEW HAULING GROUNDS

There has always been a tendency among the Commander Islands fur seals, at least among the bachelors, to haul out in new places at certain seasons. This was noticed in 1882 and 1883, but at that time it was attributed to the continued expansion of the rookeries, which compelled the bachelors to occupy new ground as they were being crowded out of the breeding area. Thus on Bering Island the beach at Kisikof (Tisikof) (Plate 94, Asiatic Fur-Seal Islands) was taken possession of in 1882; similarly on Copper Island bachelors at Glinka were hauling out in Gorelaya Bukhta north of Lebiazhi Mys and at the other end at Kulomakh beyond Babinskaya Bukhta. At the latter place in 1895 there were a few half bulls left when on August 2 of that year Mr. Grebnitski and the writer camped on that very beach. Likewise at Lebiazhi Mys only bachelors formerly hauled out. It seems, however, as if with the diminishing rookeries the cows, possibly attracted by the half bulls, that had hauled out there and become unduly numerous in proportion, must also have come ashore at some of these points, thus creating new breeding grounds; for in 1910 Suvorof reports 700 cows and a number of bachelors at Lebiazhe and 200 cows and 200 black pups at Babitche, though in neither place did he see any bulls.

It should therefore, perhaps, not cause great surprise that in 1921 and 1922 seals were reported to have hauled out on Bering Island not far from Northwest Cape, and at the southeastern extremity of Copper Island as early as 1917. In fact, it was at this recently formed hauling ground that the Japanese raiders, to be mentioned later on in this report, were caught killing seals. It was said by the natives on Bering Island that the seals hauled out near Northwest Cape consisted of some bulls and many females, as well as bachelors. However, it was expressly stated that no black pups were seen, and consequently the gathering did not as yet represent a new breeding ground. The ability of the natives to distinguish females and bachelors on shore at some distance is not always to be trusted, as the writer has had opportunity to observe on several occasions. We have even seen them quarrel over individual seals in the mixed drives on Bering Island. On the other hand, if cows returning from the feeding grounds to the northwest of the island should happen to pass by a band of half bulls and bachelors hauled out on a beach or reef there would be nothing surprising in their going ashore, either for a rest or a frolic. With the large number of superfluous bulls and half bulls on the Bering Island North Rookery it is quite likely that some of them hauled out by themselves in their search for stray cows. It is therefore improbable that we have here to deal with the incipient formation of new rookeries, although it is possible that when bulls are disproportionately abundant new breeding grounds may become established in just such a way.

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[6] "Palata [in 1882 and 1883] to the looker-on coming over the mountains, was probably the most impressive rookery view in the whole Commander Islands group. The solid blackening masses of breeding seals, filling the gulley to overflowing and extending under the bluffs and along the beach on both sides, was a sight never to be forgotten." (Asiatic Fur-Seal Islands, p. 145).

SUMMARY OF CONDITIONS IN 1922

In view of the above, the condition of the Commander Islands seal rookeries in 1922 must be characterized as highly deplorable. Large and flourishing rookeries, the breeding population of which as late as 1897 was still to be reckoned in thousands, had entirely vanished, while those remaining had shrunk to about one-tenth of what they were at that time.

In addition to this numerical decline there is another ominous circumstance to be recorded, which bodes ill for the future of the Commander Islands herd, viz, the great superabundance of old males on the breeding grounds. The evil effects of the five years' prohibition of killing after the conclusion of the treaty of 1911, which in spite of the predictions of experts was established on the Pribilof Islands, have proved even more disastrous on the Commander Islands. With the number of seals fallen below the 18,000 mentioned in Article XII of the treaty, the continued suspension of land killing of males except such as may be necessary for the support of the natives of the islands is bound to increase the handicap of the herd. The disorganization of the orderly rookery service, the trampling of the newborn seals, and, as mentioned above, the possibility of the unmated bulls attempting to start rival rookeries, are logical consequences of the policy of leaving the management of biological problems like those involved in this business to persons unversed in such matters.

EXPLANATION OF CONDITIONS

The debacle of the Commander Islands fur-seal herd is not of to-day or yesterday; it dates back to the beginning of pelagic sealing on the Asiatic side of the North Pacific Ocean. It will not be necessary to go into detail with regard to the origin and early phases of this destructive business, as they have already been fully dealt with in a previous report (Asiatic Fur-Seal Islands, pp. 190–216); and it will suffice merely to quote from the summary of that paper on page 203:

> * * * the known pelagic "Asiatic catch" from 1892–1897 was about 295,000 skins. Allowing 8,000 skins for the Kurils and Tiuleni, the *known* loss in that period to the Commander Islands herd was about 287,000 seals, apart from the loss of wounded ones, etc. The number of seals

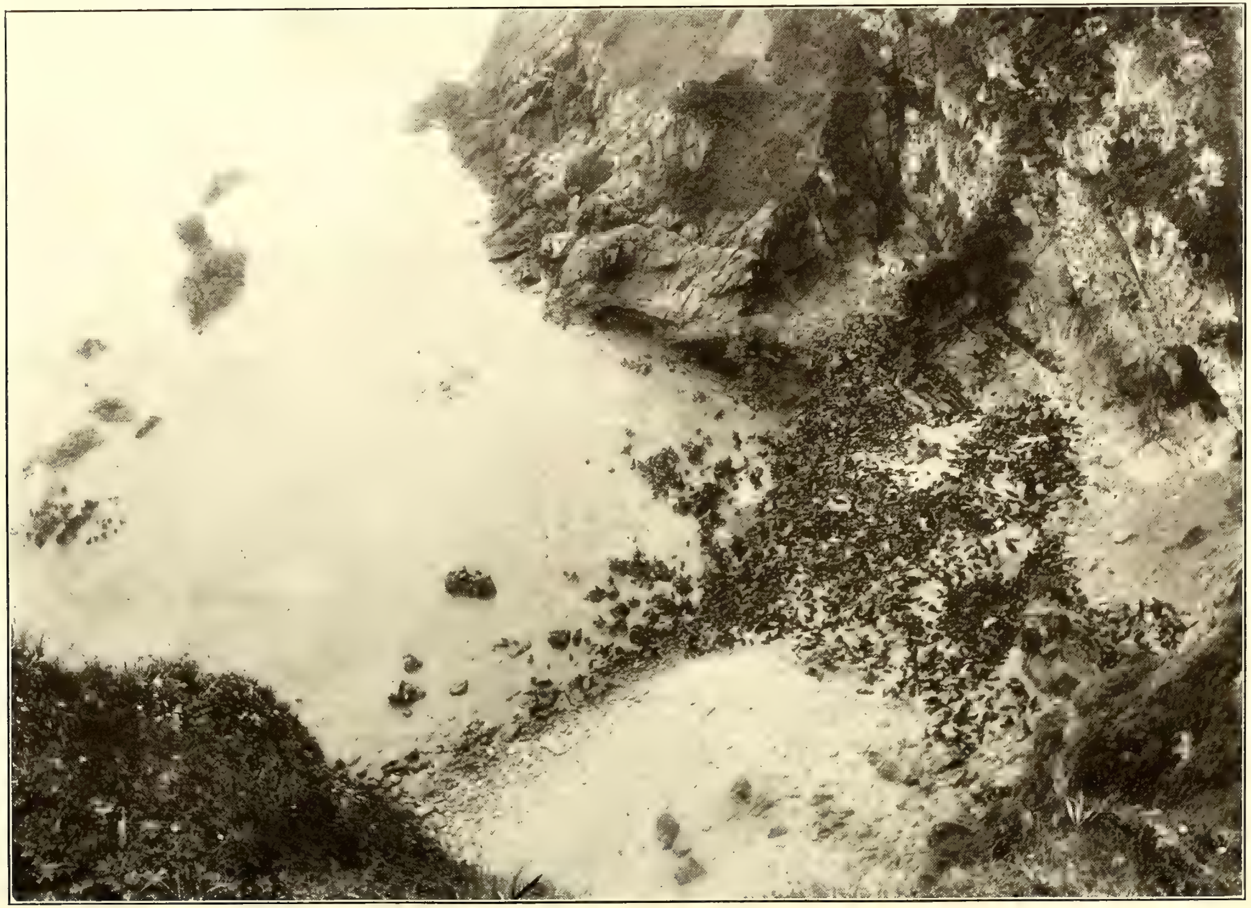

FIG. 9.—Sikatchinskoye Rookery, Copper Island, August 21, 1897, looking toward Stolbi

killed on the islands in the same period was 119,708. The pelagic *catch* was therefore considerably more than twice as large as that on the islands, while the loss to the herd from that cause was much greater, due to starved pups and seals shot but not secured. It is certainly no exaggeration to say that *the actual loss to the herd in those six years has averaged 100,000 a year, more than one-half of which were females,* * * *.

It will thus be necessary only to pick up the historical thread of the destruction since the close of the investigations of 1897.

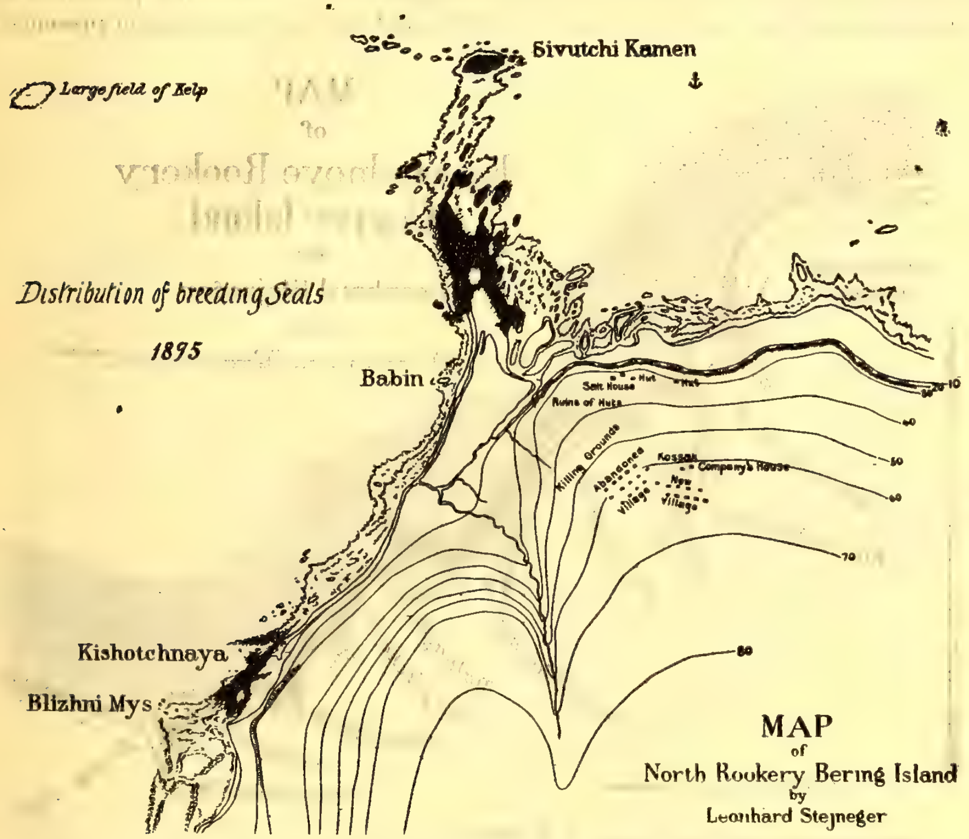
Sivutchi Kamen
Large field of Kelp
Distribution of breeding Seals
1895
Babin
Salt House
Hut
Hut
Ruins of Huts
Killing Grounds
Abandoned Village
Kossak
Company's House
New Village
10
20
30
40
50
60
70
80
Kishotchnaya
Blizhni Mys
MAP
of
North Rookery Bering Island
by
Leonhard Stejneger

FIG. 10.—North Rookery, Bering Island, showing distribution of breeding seals in 1895, according to Stejneger

HISTORY OF THE COMMANDER ISLANDS FUR-SEAL ROOKERIES AND FUR-SEAL INDUSTRY SINCE 1897

CONDITIONS AT THE END OF 1897

Two factors played an important rôle in the decrease of seals on the Commander Islands—the action of the Russian administration, which, in negotiations with the British pelagic sealing interests, accepted the 30-mile zone limit without time restriction, and the optimism of the local officials, whose estimates of the number of seals still on the rookeries were based wholly upon the so-called counts of the natives and their Cossack overseers, whose ideas of numerical figures that exceeded 10,000 were very fantastic indeed. On one occasion a Cossack, being told by Governor Grebnitski to count the seals on Bering North Rookery, returned within an hour and reported having counted considerably more than 100,000 seals.

In 1896 the writer reluctantly made an estimate of the number of seals breeding on the rookeries of both islands, claiming for it only a remote approximation, the chief merit of which was that it would serve to eliminate fanciful estimates that had no foundation in any tangible facts. The figure presented was 65,000 breeding seals on both islands, which would presume a maximum presence of about 36,000 females (including 2-year-olds) at any one time; but for the same year the assistant administrator estimated the number of cows on both islands at about 135,000.[7] No wonder they went on killing as they did.

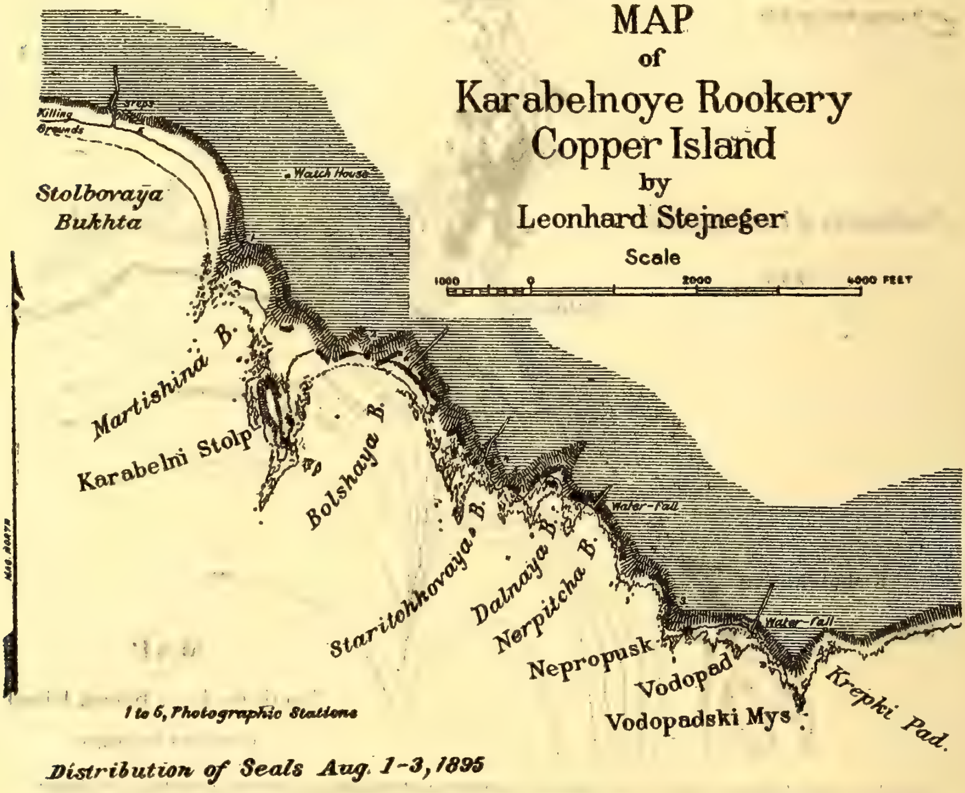
MAP
of
Karabelnoye Rookery
Copper Island
by
Leonhard Stejneger
Scale
1000
0
2000
4000 FEET
Killing Grounds
Steps
Watch House
Stolbovaya Bukhta
MAG. NORTH
Martishina B.
Karabelni Stolp
Bolshaya B.
Staritchkovaya B.
Dalnaya B.
Nerpitcha B.
Water-fall
Water-fall
Nepropusk
Vodopad
Vodopadski Mys
Krepki Pad.
1 to 6, Photographic Stations
Distribution of Seals Aug. 1-3, 1895

FIG. 11.—Karabelnoye Rookery, Copper Island, showing distribution of seals in 1895, according to Stejneger

The rookeries on the Commander Islands were at that time "raked and scraped" for the last bachelor seal to such an extent that while it might have been safe to have killed 7,000 seals that year, actually 14,472 were taken, or more than twice as many. After 1897, however, additional factors appear, which make it important to review the fur-seal industry on the Commander Islands in some detail in order to fully understand what has happened to the seal herd.

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[7] Suvorof: Komandorski Ostrova, 1912, p. 179.

CONDITIONS AFTER 1897 UNTIL THE TREATY OF 1911

Pelagic sealing.—The first circumstance to be noted is that pelagic sealing, which started so destructively to the Russian herd in 1892, continued without let or hindrance. The 30-mile protected zone around the islands, without time limit, was absolutely valueless as a protection for the seals. Moreover, pelagic sealing on the Asiatic side was fully four times as disastrous, in proportion to the stock of seals, on the Russian islands as was the destruction visited on the American seals. The pelagic catch fell off so rapidly as to become unprofitable to the Canadian and Amer-

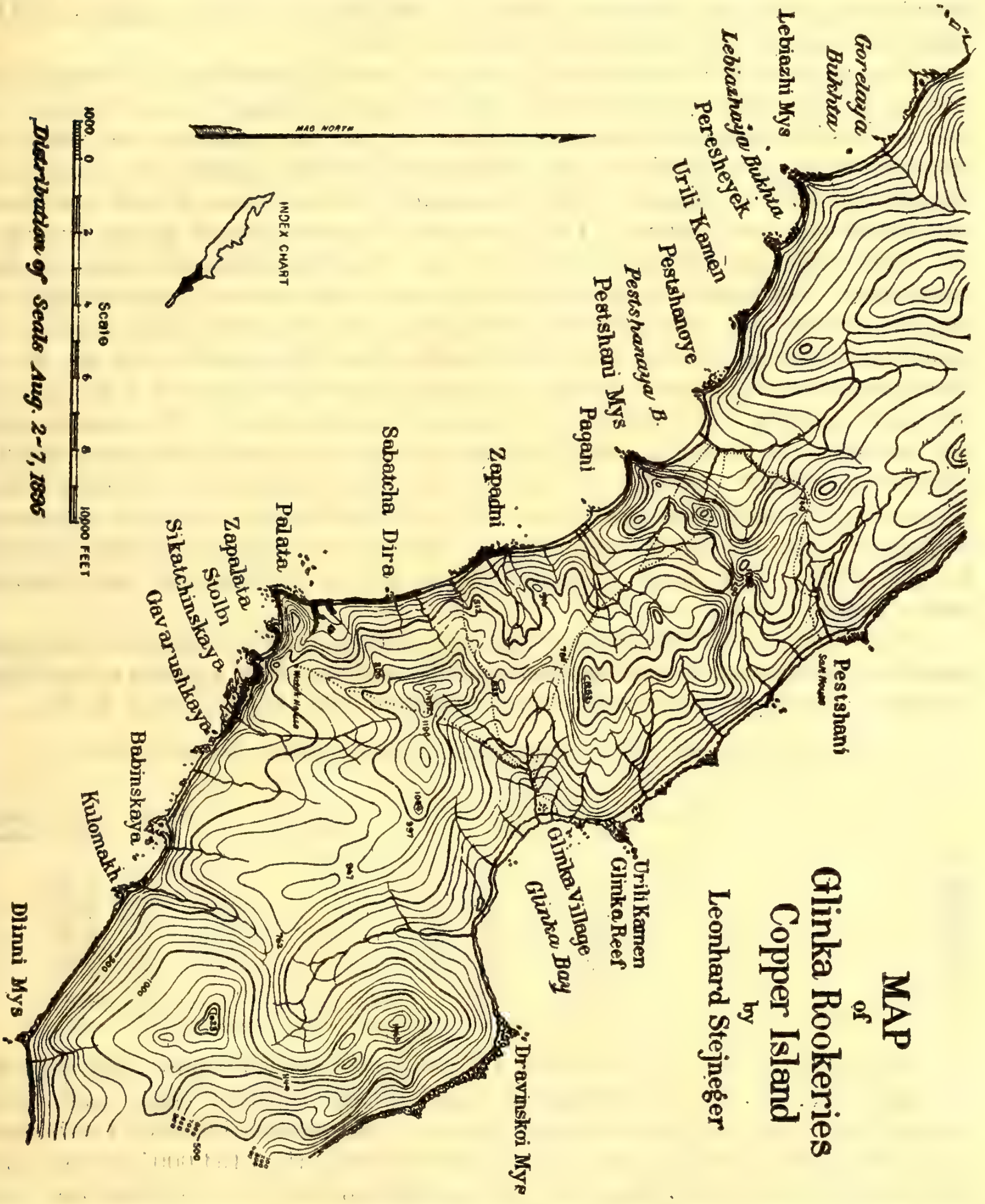
MAP
of
Glinka Rookeries
Copper Island
by
Leonhard Stejneger
Goreloya Bukhta
Lebiazhi Mys
Lebiazhaya Bukhta
Peresheyek
Urili Kamen
Pestshanoye
Pestshanaya B.
Pestshani Mys
Pagani
Zapadni
Sabatcha Dira
Palata
Zapalata
Stolb
Sikatchinskaya
Gavarushkaya
Babinskaya
Kulomakh
Dlinni Mys
Dravinskoi Myse
Pestshani
Urili Kamen
Glinka Reef
Glinka Village
Glinka Bay
INDEX CHART
MAG NORTH
Scale
1000 0 2 4 6 8 10000 FEET
Distribution of Seals Aug. 2-7, 1895

FIG. 12.—Glinka Rookeries, Copper Island, showing distribution of seals in 1895, according to Stejneger

ican schooners, which were gradually driven out of the business by the Japanese, who, because of their cheaper outfit and labor, were able to make a big profit where foreign schooners would starve. In addition, the Japanese Parliament passed a law in March, 1897, by which, from April 1, 1898, under certain conditions, a money subsidy was paid to the Japanese sealers,[8] a law that was not repealed until 1909 (Imperial Japanese Decree No. 173, June 26, 1909).

The award of the Paris tribunal, with its partial protection of a 60-mile zone around the seal islands and the close of hunting in Bering Sea until August 1, as well as the elimination of firearms, applied only to the American and not to the Russian islands. In addition, the 30-mile limit thrown around the Commander Islands was only a separate treaty agreement between Great Britain and Russia and bound no other nations. Thus when the Canadians ceased pelagic sealing on the Asiatic side and the Japanese took it up, even that slim protection was done away with. Although utterly valueless as a protection against regular pelagic sealing, the 30-mile zone had afforded a fair defense against raids on the rookeries by poaching schooners, against whom the 3 miles of the Territorial waters was of very little protection because of the frequent dense fogs which made it is an easy task for the marauders to get close up to the rookeries unobserved. The Japanese were not restricted to the use of bow and arrows, but employed the shotgun with all its terrible waste of life. As their catches steadily increased in spite of the dwindling of the herd, it is evident that the Japanese were gaining efficiency from their experience, and there is also reason for believing that the increase was due, at least partially, to the taking of oversized skins, for which the earlier Canadian and American sealers had no market.

The seriousness of the Japanese pelagic sealing and the terrible inroads made upon the Commander Islands herd may be fully understood by a glance at the following table, mainly derived from Suvorof (Komandorski Ostrova, 1912, p. 42).

Number of Japanese sealing vessels and their catch, from 1897 to 1910, inclusive

Year	Schooners	Skins taken	Skins per schooner	Year	Schooners	Skins taken	Skins per schooner
1897	14	5,247	375	1905	29	10,035	346
1898	16	4.860	304	1906	29	10,176	351
1899	12	6,518	543	1907	35	10,420	298
1900	15	7,533	502	1908	31	13,355	430
1901	19	6,945	366	1909	35	10,465	299
1902	15	7,462	497	1910	37	8,309	225
1903	21	11,240	535				
1904	28	15,698	561	Total		128,263	

If it is taken into consideration that about 30 per cent more seals were shot at than secured, and if allowance is made for one-third of these seals having escaped with their lives, it will be seen that the total number killed by the Japanese alone during those 14 years can scarcely have been less than 154,000, of which probably not less than 92,000 were cows, not to mention the loss to the herd due to the consequent starvation of the pups on the rookeries and the unborn young of the cows killed.

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[8] For more detailed provisions of the law see Asiatic Fur-Seal Islands, p. 325.

The next calamity that befell the Commander Islands seal herd was incidental to the Russo-Japanese war of 1904–5. Details of the wanton destruction are lacking, but the rookery raids, which were not uncommon before and especially after, assumed the character of willful extermination. Thus we were told that on Copper Island in 1904 a large number of Japanese landed on the Karabelni Rookery, and in addition to killing and taking the skins of a great many seals, practically all of which were cows, shot and butchered every seal they could reach for the sheer sake of destruction. This once flourishing rookery was thus to all intents and purposes exterminated during the war.

Nor did the raiding of the rookeries cease with the end of the war. The schooners came early and went late. In 1907 the first one was noticed at Copper Island on April 24 (old style). In 1908 they were observed in April, and in 1909 the first one was seen as early as February 26. Again, in 1910 the first one was reported on April 24. The piratical raiders did not confine themselves to the rookeries, but looted the houses of the natives as well. The sealing village of Glinka, inhabited only during the sealing season, was visited by the marauders on April 16, 1908 (old style), and nearly all the houses were broken into, their doors and windows smashed, and the household goods, such as dishes, linen, tools, and even the stoves, stolen; salt, sacks, and ropes were taken. The robbers even went so far as to carry away the supply of coal—about 3 tons. The same thing happened the following year when the crew of one of the schooners landed on March 6, broke the windows in 17 houses on Glinka and stole the contents (Suvorof, Komandorski Ostrova, 1912, pp. 246–247). Under conditions such as these it is a wonder that any seals were left. We shall later learn what happened to the remnant of the herd on land.

It must not be inferred that the Russians were not taking any measures against this state of affairs. The natives were organized and well armed for watch service, and during the sealing season several men-of-war patrolled the 30-mile zone and visited the islands. However, anyone familiar with the storms and fogs of the North Pacific and Bering Sea, the mountainous character of the islands, and the difficulties of transportation, must realize that effective protection against the small schooners with their reckless crews was very difficult. Nevertheless, several seizures were made during these years.

The transport *Shilka*, on August 6, 1906 (old style), arrested the schooner *Kompira Maru* 15 miles from Bering Island North Rookery. On May 16, 1908, the schooner *Miye Maru* was arrested 7½ miles from shore. Besides seals she had on board 1 sea otter and 1 blue fox, sufficient evidence of illegal catch on shore. Again, on July 25, 1909, the *Shilka* stopped the schooner *Tokiva Maru*, belonging to the firm Yeno-gono-kaisha, and confiscated 14 sea otters and 6 sealskins. On the same day the rookery guards on Copper Island caught a boat with three raiders from the schooner *Hosio Maru*, 2½ miles from the Bobrovi Rocks off the northern end of Copper Island. These few instances, however, and the punishments inflicted (the three men caught in the raid on July 25, 1909, were given sentences of three months in the Vladivostok jail) were of no avail in checking the aggressiveness of the raiders.

Sealing industry on land.—On the Commander Islands the sealing industry was in the hands of a trading and sealing company, practically the same arrangement that existed on the Pribilof Islands except that the killing of the seals was done through the agency of the Government while the company's responsibility began with the receipt of the fresh skins at the salt-house door.

In 1897 the leasing company (the Russian Seal Skin Co.) was operating under a 10-year contract from February 19, 1891, to February 19, 1901 (old style). This company, however, continued the sealing business during the season of 1901, shipping from the islands in that year 11,489 skins (Bering Island 5,438, Copper Island 5,527, and Robben Island 524), for which, at the rate of 12 rubles per skin, they paid the Government 137,868 rubles, as shown by the documents in the Bering Island archives.

On August 4, 1901 (old style), a contract for the lease of the sealing on the islands for the next 10 years from September 1, 1901, was concluded between the Russian department of agriculture and public domain and the Kamchatka Commercial-Industrial Co. much on the same conditions as previously, the company to pay 10 rubles for each sealskin, 200 rubles for sea otters of the first quality, 100 rubles for sea otters of the second quality, 18 rubles for first-class blue foxes, 9 rubles for second-class blue foxes, and 5 rubles for white foxes.[9] Headquarters of the company were in St. Petersburg, with an agent in Petropaulski.

This company, the lease to which expired on September 1, 1912, was succeeded on that date by a new company, Ivan Yakovlevitch Tchurin & Co., also known as the I. I. Choorin Co., which held the contract for the skins to September 1, 1916 (old style), when the system of leasing was abandoned and the administration of the fur industry of the islands was taken over by the fisheries bureau in Vladivostok. As the five-year closed season for seals fell within their term, they handled principally sea-otter and blue-fox skins.

Then followed the revolution, and the subsequent events, in so far as they have any bearing on the sealing industry, will be related separately.

In the three years, 1895 to 1897, when the writer investigated the Commander Islands rookeries the hauling grounds were "raked and scraped" for the last obtainable bachelor. At the same time pelagic sealers took tremendous toll of the herd at sea, which had not even the slight protection of the 60-mile zone and the closed season before August 1. There can be no doubt that the killing on land was much too close, with pelagic sealing still going on unchecked. If the estimate of the females present on the Commander Islands in 1896 were only moderately accurate, the number of male seals killed that year (14,472) would not have been justifiable even if the herd had been in prime condition and no pelagic sealing going on. As the killings are now regulated on the Pribilofs, though possibly overconservative, there would not have been taken 7,000 skins; but the worst of it was, of course, that in the same year probably 20,000 female seals belonging to the Commander Islands herd were killed at sea. The next year this toll of females was scarcely less than 12,000, yet by the same process of scraping the rookeries on the islands the company secured 13,620 bachelors.

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[9] The text of the contract, with the title *Kontrakt na sdatchu f arendu Kamtchatskomu Torgovo-Promishlennomu Obshtchestvu pushnik promishlof na Ostrovakh Komandorskikh i Tiuleniem,* is to be found as Appendix I in Suvorof's Komandorskie Ostrova, 1912, pp. 281–285

In 1898 and 1899 the number of skins taken did not much exceed 9,000, but the catches of the Japanese pelagic sealers were slowly increasing in spite of the dwindling of the herd. The lease of the Russian Seal Skin Co. was now nearing its termination, the last season under the contract being that of 1900, but extended over to the end of the 1901 season as noted above. Quite naturally, then, and especially as every seal spared on the islands meant one more possible skin for the pelagic sealers, the lessees bent every effort to get by any means whatever as many seals as possible.

It was thought by us who witnessed the "raking and scraping" of the rookeries in 1895 to 1897, when the extreme methods applied yielded respectively 16,056, 14,946, and 11,335 skins, that the limit of what was possible had been reached; but notwithstanding the facts that similar methods prevailed in 1898 and 1899 and that pelagic sealing still continued to take its toll, the lessees succeeded in taking 12,540 skins in 1900 and 10,965 in 1901.

The new lessees, the Kamchatka Commercial-Industrial Co., were not able to keep up this pace, but considering the circumstances and the condition of the herd they did pretty well, taking 7,107 skins in 1902 and 7,806 in 1903. During the disastrous years of the war (1904–5) they even took 8,319 and 8,990, respectively. However, these years brought about the final collapse of the Commander Islands rookeries. It has already been mentioned how the war was taken advantage of by the Japanese raiders to partially destroy the rookeries. It may now be told how the war, by causing enormous losses to the leasing company, also became an active factor in the ultimate demoralization of the killing on land.

While the Russians at the outbreak of the war were endeavoring by negotiations to obtain permission for the company to navigate its ships under a foreign flag, the Japanese seized the company's steamer *Kotik* in Yokohama harbor and shortly afterwards its schooner *Bobrik* in the harbor of Hakodate, less than three weeks after the opening of hostilities in January, 1904, thus crippling the company at the beginning of the sealing season, though it was able afterwards to charter the American steamer *Redondo* for the island service. This vessel, however, proved worthless, and the *Mineola*, which replaced her, was wrecked in the Okhotsk Sea near Tigil on the west coast of Kamchatka, involving a total loss of the cargo of goods and furs. During 1905 two more ships were chartered but both were captured by the Japanese in August, 1905. This capture involved a loss of 4,030 fur-seal skins. It should be added that the rookery at Robben Island, which also was included in the company's lease, was lost to the Russians from the beginning of the war. Altogether the Kamchatka company's losses were enormous, and quite naturally its managers tried to save as much out of the wreck as possible.

From 1895 to 1897 there was still a superabundance of adult male seals on Copper Island, though on Bering Island the bulls were relatively much scarcer, due to the fact that the character and situation of the rookeries were much more favorable for a close killing than on Copper Island. At that time, however, the proportion of the sexes was not such as to cause alarm if pelagic sealing could have been stopped within a short time, a hope that was perfectly legitimate in view of the unanimous recommendations made by the seal experts from England, Japan, and America at their meeting in Washington in the fall of 1897. To stop the land killing of males even for a single season, or to limit the number killed without stopping pelagic sealing, would have been not only useless but absolutely senseless, as the only possible result would have been the sparing of that many males for the benefit and encouragement of the pelagic sealers. Owing to the delay in acting upon the recommendations of the experts who investigated conditions on the islands, the seals went to their destruction, which was terribly accelerated by the circumstances detailed above.

The Russian authorities on the islands must have seen the approaching catastrophe, but their optimism apparently was not seriously shaken, since it was possible to average nearly 9,400 skins during the years preceding the debacle of the war. It then became plain not only that the breeding herd had greatly decreased but that the number of breeding males in particular was becoming alarmingly small. In 1904 the natives at the North Rookery on Bering Island reported to the administrator of the islands that only 25 old bulls were left and that bachelors were exceedingly scarce. To counteract this disproportion of the sexes, and also to make up for the loss of the bachelor skins, the company proposed that they should be allowed to stop killing bachelors and to kill females instead. This was objected to, but by a revival of the old fiction of virgin and superannuated cows the company succeeded in obtaining from the Ministry of Agriculture and Public Domain in St. Petersburg permission to kill 8,000 unimpregnated cows and 1,000 bachelors. As the permission arrived after the opening of the season, 1,608 bachelors but only *6,282 females* were killed that year (1905).

Thus began a new chapter in the destruction of this herd, since, as was to be foreseen, this unique method of restoring the equilibrium between the sexes, far from accomplishing its purpose only hastened the destruction. During the next two years comparatively few females were recorded killed in the official documents, but their skins were taken unofficially and without permission, the understanding being that only nonpregnant or superannuated cows were to be killed.

At this juncture occurred the death of Nikolai Aleksandrovitch Grebnitski (fig. 13), who had been the Government manager of the islands for 30 years. When he first landed on Bering Island on August 21, 1877, the sealing industry was still on the upward grade, reaching its zenith during the following 10 years. He was a capable administrator, who was looking out for the interests of the natives in their relations with the leasing companies, and he established sensible and suitable rules for the regulation of the sealing business and blue-fox and sea-otter hunting. Grebnitski, who had studied at the University of Odessa and in Germany, had considerable biological training and was thus well qualified for his position. It may be safely said that in the days before the beginning of pelagic sealing Grebnitski knew all that could be learned about the seals on land and acted intelligently upon his knowledge. Moreover, he was practically the only man in the whole Russian Government who knew anything about the seals and the sealing business; but, of course, when pelagic sealing started in earnest on the Asiatic coast he was practically helpless and can hardly be blamed for the Russian failure to secure any practical protection for the Commander Islands seal herd.

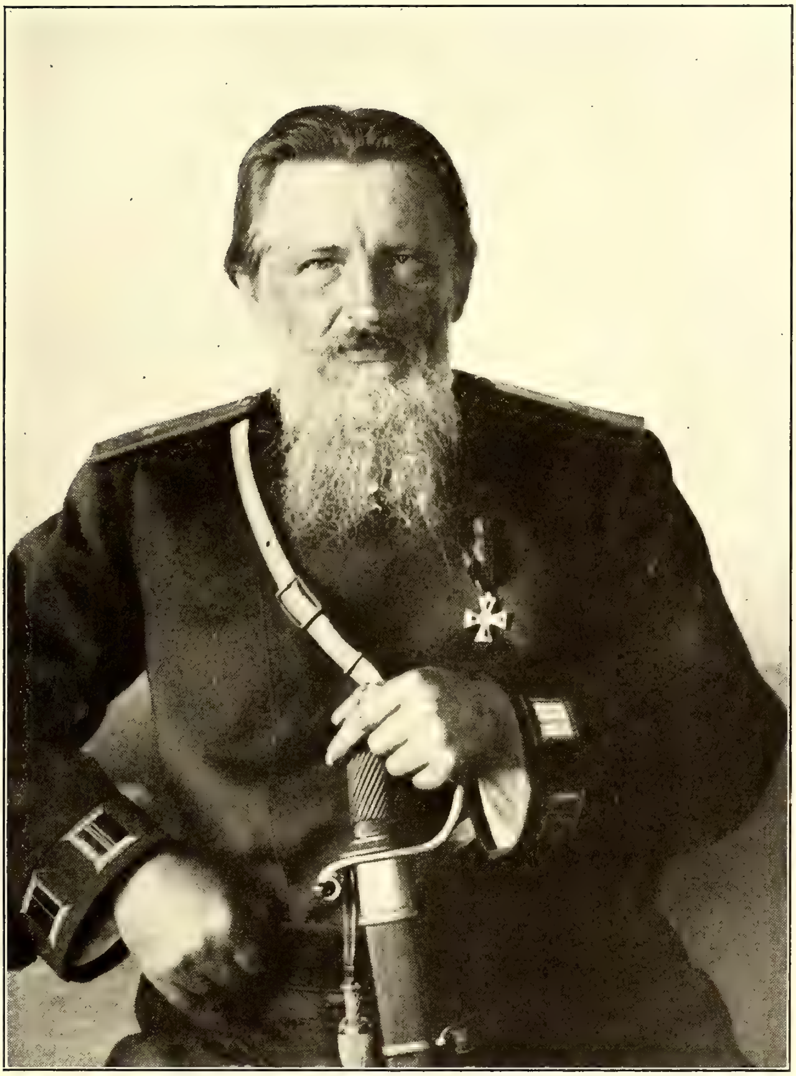
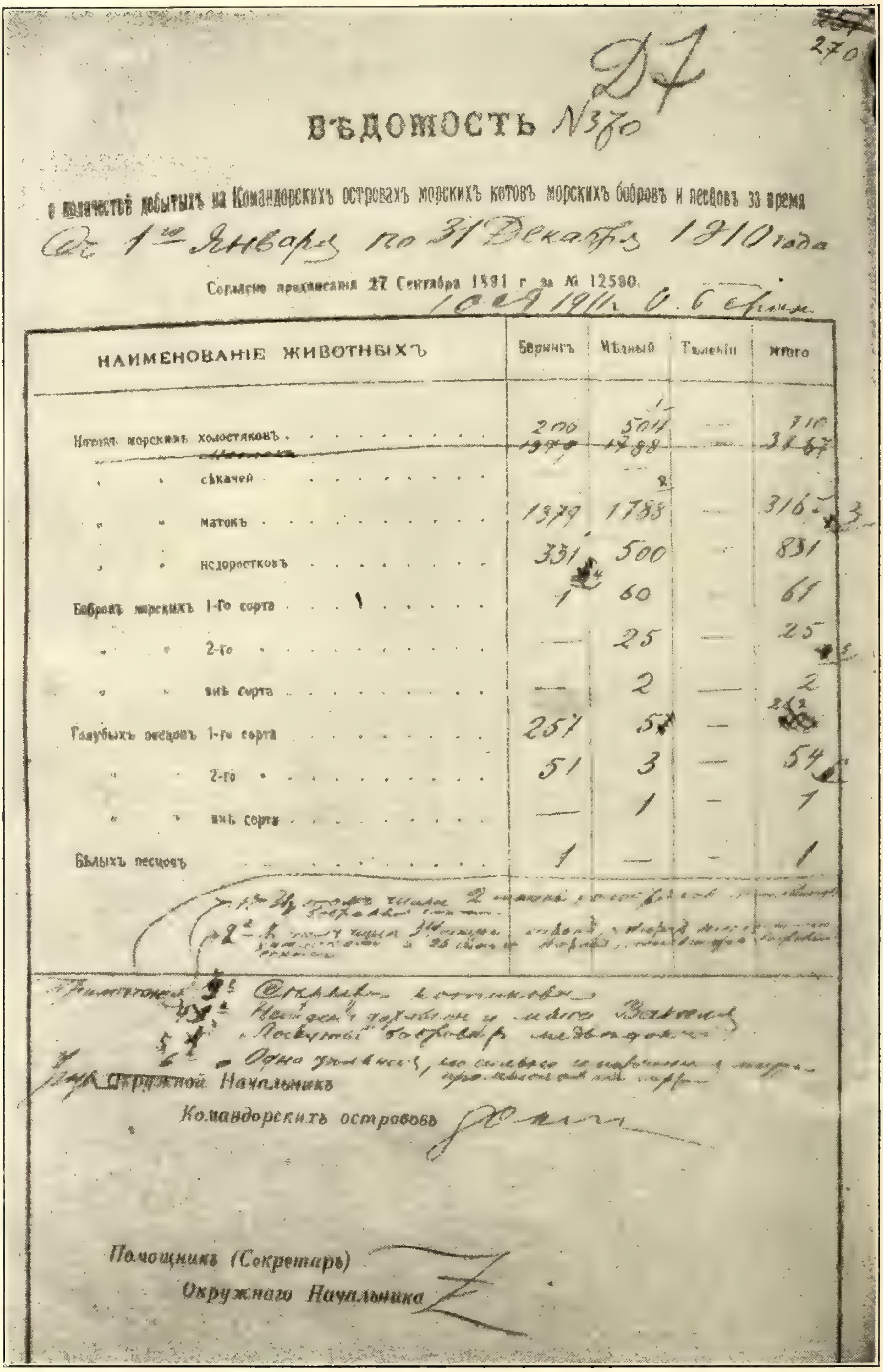


Fig. 13.—Nikolai Aleksandrovitch Grebnitski, Administrator of the Commander Islands from 1877 to 1907



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ВѢДОМОСТЬ №370

о количествѣ добытыхъ на Командорскихъ островахъ морскихъ котовъ морскихъ бобровъ и песцовъ за время

Съ 1-го Января по 31 Декабря 1910 года

Согласно предписания 27 Сентября 1891 г. за № 12580.

10 [illegible] 1911 г. [illegible]

НАИМЕНОВАНІЕ ЖИВОТНЫХЪ	Берингъ	Мѣдный	Тюленій	Итого
Котиковъ морскихъ холостяковъ	200 ~~1379~~	504 ~~1788~~	—	710 ~~3167~~
" " сѣкачей		2		
" " матокъ	1379	1788	—	316
" " недоростковъ	331	500	—	831
Бобровъ морскихъ 1-го сорта	1	60	—	61
" " 2-го	—	25	—	25
" " внѣ сорта	—	2	—	2
Голубыхъ песцовъ 1-го сорта	251	5[illegible]	—	2[illegible]2
" " 2-го	51	3	—	54
" " внѣ сорта	—	1	—	1
Бѣлыхъ песцовъ	1	—	—	1

1. Изъ этого числа 2 [illegible]

2. [illegible]

Примечание: 3. [illegible]

4. [illegible]

5. [illegible]

6. [illegible]

Окружной Начальникъ

Командорскихъ острововъ

Помощникъ (Секретарь)

Окружнаго Начальника

Fig. 14.—Copy of "Viedomost" or "Report on the number of fur seals, sea otters, and arctic foxes taken on the Commander Islands during the period from January 1 to December 31, 1910." From original in the Bering Island archives

No measure short of total stoppage of pelagic sealing could have prevented the final destruction of the seal herd, though, of course, the excessive scraping of the rookeries for male seals and the tragic killing of females toward the end of his administration and against his protest naturally hastened the process.

Col. Nikolai Pavlovitch Sokolnikof, who for 10 years had been administrator of the Anadyr district, was transferred to the Commander Islands after the death of Grebnitski. Upon his arrival in 1907, finding that the killing of cows was practiced upon the initiative and responsibility of the assistant manager, he put a stop to it that same fall and protested earnestly against it to the department in St. Petersburg without avail. The department issued a permit for 1909 to kill 4,000 cows and 1,500 bachelors, and in order to make sure that this maximum should be reached the leasing company agreed to accept up to 20 per cent of stagy skins. However, not more than 3,155 cows were secured, though the total quota was exceeded by 311 skins.

When this document was discovered in the archives of Bering Island in 1922, we knew already that cows had been killed quite extensively, but were so amazed to see this unblushing Governmental acknowledgment that a photograph of the "Viedomost" (herewith reproduced as fig. 14) was taken as a memento and as proof. The work begun in 1909 was continued in 1910, only there were fewer seals to take. The result on both islands was as follows:

Sealskins taken on Commander Islands, season of 1910

Island	Bachelors	Cows	Total
Bering Island	206	1,105	1,311
Copper Island	502	1,492	1,994
Total	708	2,597	3,305

In order to obtain this number it was necessary to extend the killing season to August 31 on Copper Island and to October 2 on Bering Island. In fact, of the 3,305 skins taken only 863 were secured before August 1, on which date, in the past, killing usually stopped. Finally, in the years 1907 to 1909 over 2,500 gray pups were killed in the fall for food for the natives. Just exactly what was the proportion of the sexes among these is not known, but certainly they were not all males.

The alarming reports about the condition of the rookeries, the approaching expiration of the lease of the Kamchatka company, and the proposed negotiations for a treaty to abolish pelagic sealing induced the Ministry of Agriculture and Public Domain to make an investigation in order to obtain information at first hand. Evgenij K. Suvorof, who was sent from St. Petersburg in 1910, does not seem to have had any previous experience with the fur-seal industry or the fur seals. This, however, was not of much significance, for all he could do was to confirm the utter demoralization of the whole business. It was only when he attempted to explain certain features of the debacle and its causes, and also when he attempted to make an estimate or a "count" of the number of seals remaining and the classes of seals composing the herd, a feature which will be referred to later, that his inexperience became a decided handicap. He undoubtedly did his best, and his report contains a large amount of valuable information which has been drawn upon quite extensively, but so far as the fate of the seal herd was concerned it did not and could not possibly have any influence. It was too late.

Condition of the rookeries in 1910.—Arriving on the Commander Islands in 1910, one of Suvorof's first endeavors was to ascertain the actual number of seals on the rookeries. Apparently all possible methods of ascertaining the number of seals on the Pribilof Islands had been tried, such as calculation of the area occupied by the herd divided by the theoretical space in square feet occupied by a seal; counting the cows in a number of harems, averaging their number per harem, then counting the harems (that is, old bulls) on the rookery; counting from a distance the number of seals on a certain area of apparent normal density and then applying the figures obtained to the whole rookery. Every one of these methods, however, had to be abandoned and the conclusion reached that there is only one reliable method, viz, to corral, drive off, and actually count every black pup on the rookery. Their number ascertained, the number of the breeding females, only a varying proportion of which are present at the same time on the rookeries, is consequently ascertained

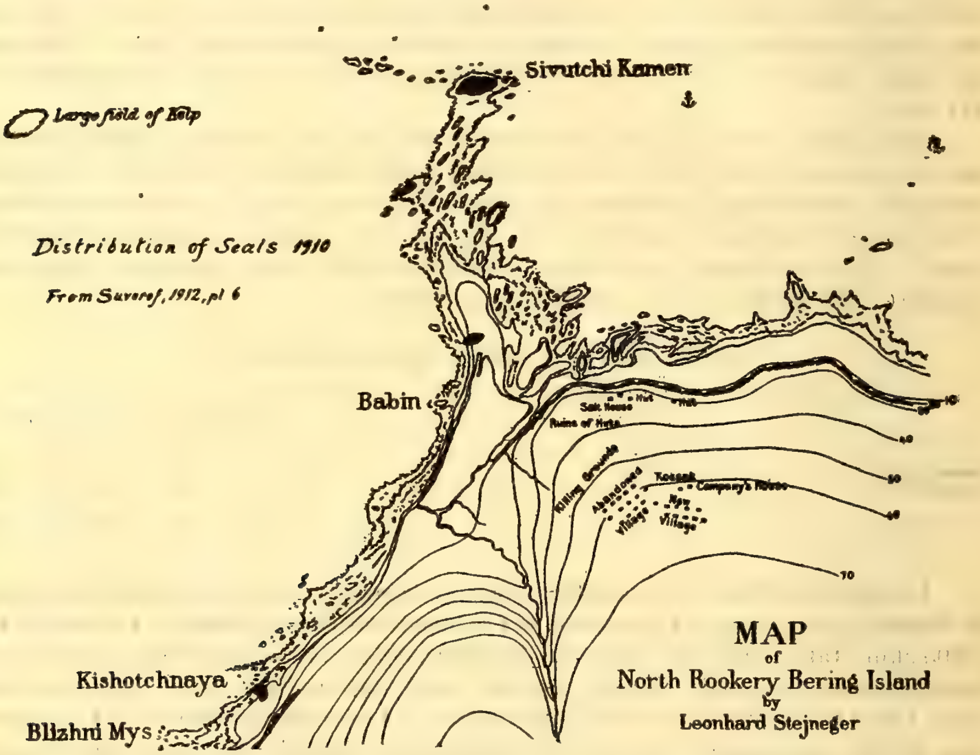
Sivutchi Kamen
Large field of Kelp
Distribution of Seals 1910
From Suvorof, 1912, pl 6
Babin
Hut
Hut
Salt House
Ruins of Huts
Killing Grounds
Abandoned Village
Kossak
Company's House
New Village
10
40
50
60
70
Kishotchnaya
Blizhni Mys
MAP
of
North Rookery Bering Island
by
Leonhard Stejneger

FIG. 15.—North Rookery, Bering Island, showing distribution of seals in 1910, according to Suvorof

with exactness, and that is the only figure that is of prime importance. With that given, the number of the other classes can be observed and computed with sufficient accuracy for all practical purposes.

In 1897 the writer declared that a count of the seals such as was undertaken on the Pribilofs could not be carried out on the Commander Islands owing to the difference in character of the rookery beaches on the two groups of islands.

With the excessive shrinkage of the number of seals during the next 13 years, however, it seems certain from what was seen on North Rookery, Bering Island, in 1922, that a count of the black pups would have been feasible there in 1910, though it would still be impracticable on most of the rookeries on Copper Island. Moreover, on account of lack of suitable means of transportation, one person would be utterly unable to cover all the rookeries during the short period in which such a count must be made.

As Mr. Suvorof had no previous practical experience and probably had no detailed description at hand of the technique of counting the pups as developed on the American islands, he was restricted to his own resources and the application of some of the methods mentioned above, as definite statistics and not vague estimates—which can be of value only when done by persons of wide experience and tried judgment—were evidently expected by the authorities in St. Petersburg, who had been accustomed to receive most minute figures from the previous administration of the island based on the fantastic "counts" which the native guards, stationed at the various rookeries, made at certain intervals during each season. When confronted with the Bering Island rookeries—Reef and Kishotchnoye—his first attempt was directed at ascertaining the number of seals present by the area method. Red and white marks and signals were painted all over the two rookeries, and calculations of various sorts started. Unfortunately, or fortunately, this work had to be left unfinished, as by the middle of July (old style) he had to leave for Copper Island. Here that method was plainly impossible.

By that time he had also discovered, what we others had learned long before, that even if one can get near enough to even a depleted rookery to start an autoptic count of the seals in sight, "part of the seals always slip away from the counting, and the figures obtained invariably prove lower than the actual ones. * * * Part of the animals are in motion, some come out of the water, others wend their way to the sea; many are concealed by the unevenness of the beach, by jutting rocks and cliffs. Many new-born pups, in particular, are concealed in the crevices between the rocks." He also observed that the weather, the temperature, and the time of the day made a big difference. Nevertheless, he decided that this was the only method possible on Copper Island, and he believed "that the error of the per capita count of the adults would not exceed 10 per cent and of the new-born pups 20 to 25 per cent," adding that "the method of area never gave such exactness" (Komandorskie Ostrova, 1912, pp. 181–2).

During the latter part of July and the beginning of August, 1910 (old style), therefore, he "visited all the Copper Island rookeries and carefully counted all the black pups lying on the beach and splashing in the near-shore zone." To the number thus obtained he "added 14½ per cent for the females without pups, and in this way arrived at the approximate number of cows on the given rookery." It turned out that his figures "approached sufficiently near the autoptic estimate of the rookery guard" on Copper Island. With regard to the Bering Island rookeries, where his "area method" had proved a failure, he had to devise a different method, and as his figures on Copper Island had "approached sufficiently near" those of the watchmen, he assumed that those of the Bering Island guard were equally reliable. He consequently adopted the latter, applying to them, however, a "correction coefficient" deduced from a comparison of his own count on Copper Island with the eye determination of the watch. In this way he obtained the figures of the following table, which in his opinion approximately express the number of animals on the rookeries, the number of bachelors present being practically negligible. He remarks specificially that the estimate relates to the number of seals left after 1,017 cows and 500 bachelors had been killed.

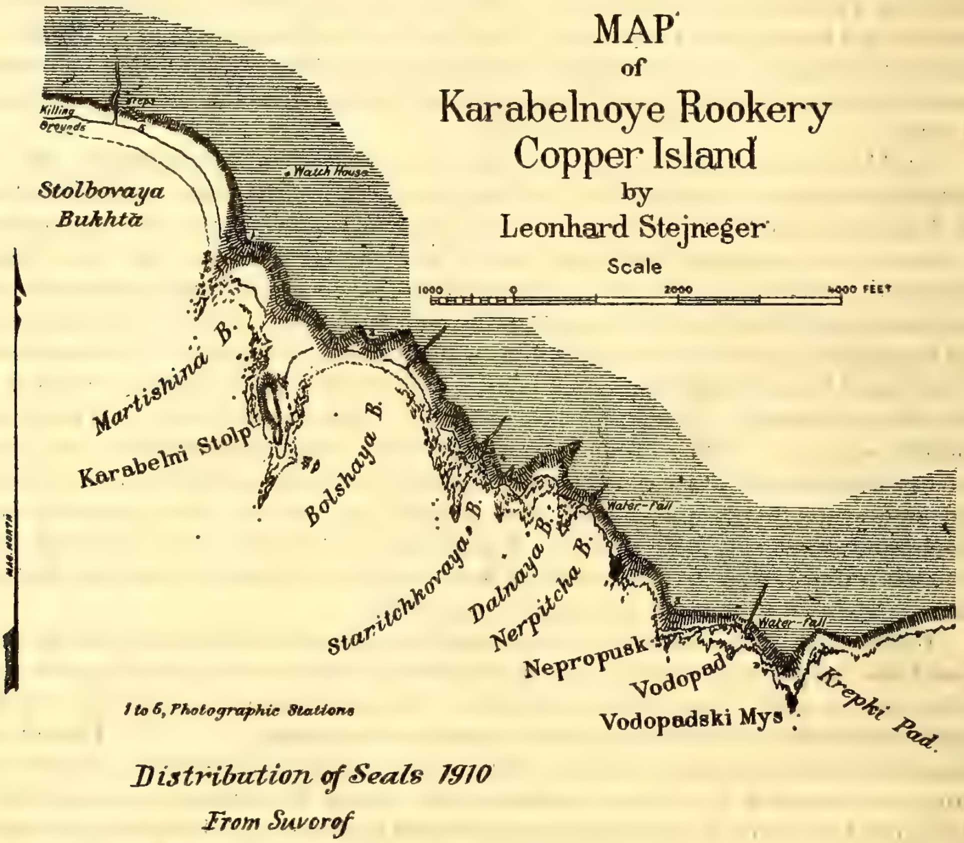
MAP
of
Karabelnoye Rookery
Copper Island
by
Leonhard Stejneger
Scale
1000
0
2000
4000 FEET
Killing Grounds
Steps
Watch House
Stolbovaya Bukhtă
Mag. North
Martishina B.
Karabelni Stolp
Bolshaya B.
Staritchkovaya B.
Dalnaya B.
Nerpitcha B.
Water-Fall
Nepropusk
Vodopad
Water-fall
Vodopadski Mys
Krepki Pad
1 to 6, Photographic Stations
Distribution of Seals 1910
From Suvorof

FIG. 16.—Karabelnoye Rookery, Copper Island, showing distribution of seals in 1910, according to Suvorof

Suvorof's table of seals on the Commander Islands rookeries about the middle of August (new style), 1910

Rookery	Half bulls	Bulls	Cows	Black pups
COPPER ISLAND				
Glinka rookeries:				
Gavarushetche		1	50	25
Siskatchinskoye (Vodopad)		7	570	500
Zapalata		8	1, 350	1, 200
Palata		3	550	500
Zapadnoye		6	600	550
Urili		20	1, 250	1, 100
Lebiazhe			[1] 700	
Babitche			200	200
Karabelnoye rookery:				
Nerpitchi Kamen		3	150	124
Total		48	5, 420	[2] 4, 200
BERING ISLAND				
North Rookery:				
Reef	1	7	1, 800	1, 400
Orlof Kamen		2	150	130
Sivutchi Kamen		5	250	220
Kishotchnoye		2	200	160
In water near rookery			[3] 1, 600	
Total	1	16	4, 000	[2] 2, 000
Total (both islands)	1	64	9, 420	6, 200

[1] Partly bachelors.
[2] These figures are those given by Suvorof; the actual summation gives 4,199 and 1, 910, respectively.
[3] Approximate.

The corresponding totals of the watchmen are given as follows:

	Cows	Black pups
Copper Island	7, 070	5, 755
Bering Island	4, 120	2, 550
Both islands	11, 190	8, 305

It is not easy to see how he has arrived at these figures and how he applied the "correction coefficient," as it appears from his tables that his own estimate on Copper Island differs much more from that of the Copper Island guards than the accepted figures for Bering Island do from those of the Bering Island guards. However, much as this census probably differs from the actual figures, it is a sufficiently eloquent demonstration of the terrible straits to which the Commander Islands rookeries had been reduced by 1910. If we add to this that afterwards during the same year 1,580 more cows and 208 bachelors were killed [10] and imagine the number of black pups that must have starved to death, as their mothers were killed both on land and at sea, we get a vivid picture of the conditions that existed at the close of the season of 1910. To complete the picture of destruction it should be realized that because of the decreasing number of male seals taken, the natives were allowed to kill gray pups in the fall for food. The number of gray pups thus killed in the three years preceding 1910 averaged 860. How many of these were females it is not possible to say.

Suvorof's figures receive additional confirmation by his maps. These are only diagrammatic representations on small-scale copies of the rookery maps published by the writer in 1896 and 1898. His data, however, have been transferred to the latter, as shown in Figures 15, 16, and 17, and to better show the destruction the distribution of the seals as the writer mapped it in 1895 has been reproduced on the same scale (figs. 10, 11, and 12).

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[10] Altogether in 1910 there were killed on the Commander Islands 2,597 cows and 708 bachelors; of these 1,017 cows and 500 bachelors had been killed before the census was taken.

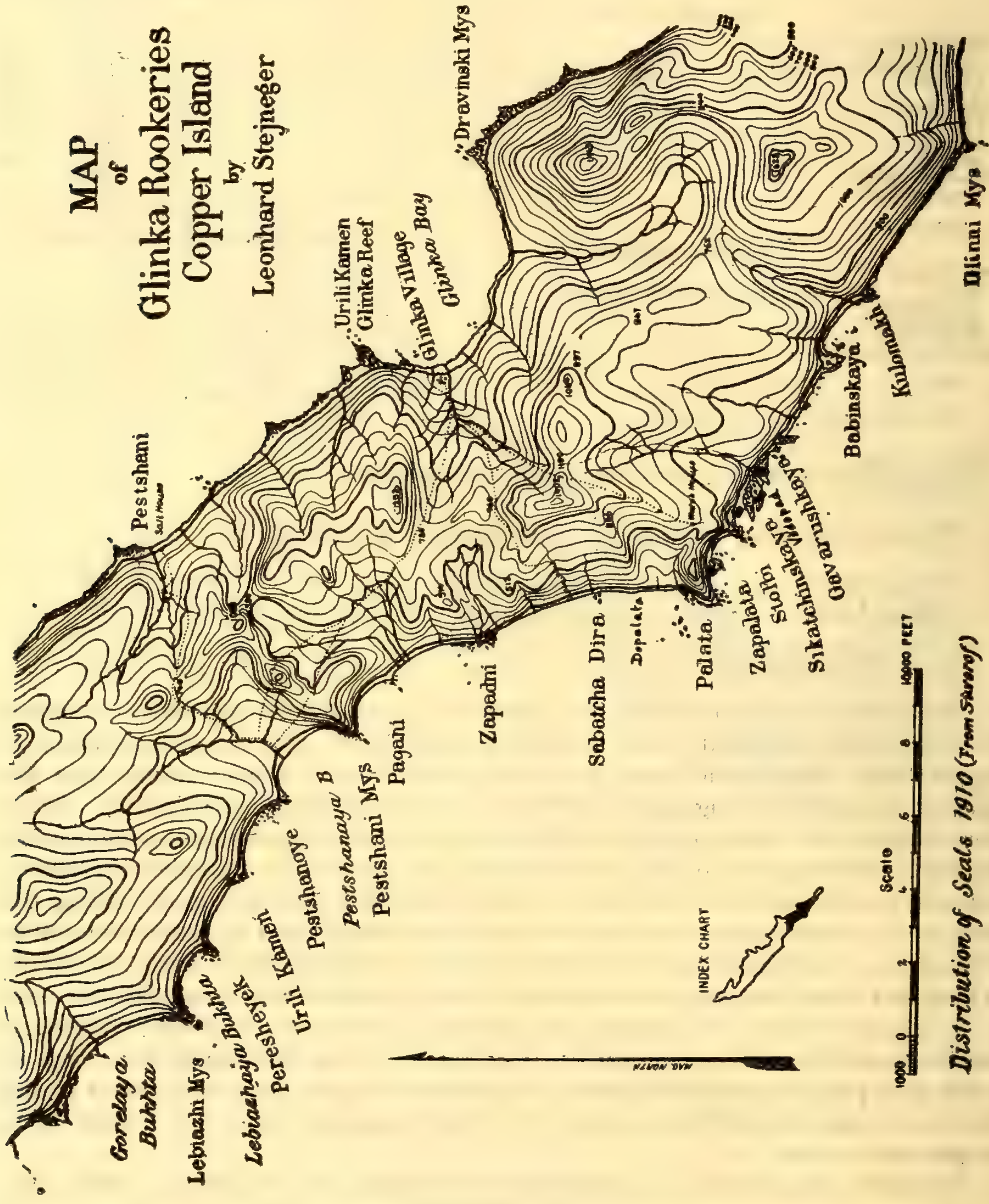
MAP
of
Glinka Rookeries
Copper Island
by
Leonhard Stejneger
Dravinski Mys
Urili Kamen
Glinka Reef
Glinka Village
Glinka Bay
Pestshani
Salt House
Dlinni Mys
Kulomakh
Babinskaya
Govarushkaya
Sikatchinskaya
Stolb
Zapalata
Palata
Dopalata
Sabatcha Dira
Zapadni
Pagani
Pestshani Mys
Pestshanaya B
Pestshanoye
Urili Kamen
Peresheyek
Lebiazhaya Bukhta
Lebiazhi Mys
Gorelaya Bukhta
INDEX CHART
MAG. NORTH
Scale
1000 0 2 4 6 8 10000 FEET
Distribution of Seals 1910 (From Suvorof)

FIG. 17.—Glinka Rookeries, Copper Island, showing distribution of seals in 1910, according to Suvorof

THE TREATY OF 1911

It had become obvious to everybody by this time, to those who had profited by the pelagic sealing as well as to the powers owning the breeding grounds, that some arrangement would have to be made if the seal herds were not to be exterminated, to the permanent loss of all parties. Fourteen years previously sealing experts of all the powers interested had agreed as to the essential facts and the best methods for protecting the seals, but political and financial considerations had prevented action upon their recommendations. Such considerations would obviously be of no importance when the seals themselves should have ceased to exist, hence the belated willingness of the four governments to compromise their claims.

Under the auspices of the United States Department of State an international conference was convened in Washington on May 5, 1911, for the purpose of concluding a treaty affecting the fur seals of the North Pacific Ocean. The powers attending the conference were Great Britain, Russia, Japan, and the United States. The principle that guided the negotiations seems to have been an acknowledgment of the right of the pelagic sealers to compensation for giving up their preying on the seal herds outside territorial waters. At any rate, the governments possessing seal rookeries agreed to pay the others 15 and 10 per cent of the sealskins taken. A treaty was signed on July 7, 1911, and after ratification became effective on December 15, 1911, and was to continue in force for a period of 15 years from that date and thereafter until terminated by 12 months' written notice given by one or more of the parties to all of the others, which notice may be given at the expiration of 14 years or at any time afterwards.

By this treaty pelagic sealing was forbidden in the waters of the North Pacific Ocean north of 30° north latitude and including the Seas of Bering, Kamchatka, Okhotsk, and Japan, with the exception that "Indians, Ainos, Aleuts, and other aborigines" may carry on pelagic sealing in canoes without firearms under certain conditions specified, among them that these aborigines must not be "under contract to deliver the skins to any person." There is nothing, however, forbidding these aborigines to sell the skins. Otherwise no person or vessel shall be permitted to use any part of the territory of any of the signatory powers for any purposes whatsoever connected with the operations of pelagic sealing, nor shall any sealskins not certified to have been taken legally be permitted to be brought into the territory of any of these powers. The latter agree to enact and enforce such legislation as may be necessary with appropriate penalties for violations, and to cooperate with each other in taking such measures as may be appropriate and available for the purpose. In addition, the United States, Japan, and Russia agree to maintain a guard or patrol in the waters frequented by their respective seal herds. This would entitle Russia to maintain a guard off the Japanese coasts during the winter and spring migrations of the Commander Islands seals.

This apparently throws the burden of protecting the seals at sea against the illegal pelagic sealing by nationals of the other powers upon the one in whose territory the herd breeds, thus relieving the government of the offending sealers of any obligation to interfere with them, except to prevent them from bringing the illegally taken skins into its territory and to try the offenders and impose upon them penalties of its own making, when such offenders shall have been delivered to its authorized official by the naval or other duly commissioned officer of the government making the seizure. In other words, in order to protect its seals against pelagic sealers the Russian Government must have an effective guard not only in summer in the waters surrounding the Commander Islands within a radius of at least 150 miles around the islands, as the breeding seals are known to go that far to sea in search of food, but also in winter and spring along the coasts of Japan from the latitude of Yokohama to and including the Kuril Islands. The Japanese Government is under no obligation to interfere with its own subjects in all that big stretch of ocean except to forbid them the use of its ports, etc., to prevent them from bringing in the illegally taken skins, and to try and punish them according to Japanese law when they have been seized by a Russian officer and duly handed over to an authorized Japanese official.

Article XII of the treaty is of particular interest to the Commander Islands sealing industry. It reads as follows:

> It is agreed on the part of Russia that of the total number of sealskins taken annually upon the Commander Islands, or any other island or shores of the waters defined in Article I subject to the jurisdiction of Russia to which any seal herds hereafter resort, there shall be delivered at the Commander Islands at the end of each season fifteen per cent (15%) gross in number and value thereof to an authorized agent of the Canadian Government, and fifteen per cent (15%) gross in number and value thereof to an authorized agent of the Japanese Government; provided, however, that nothing herein contained shall restrict the right of Russia at any time and from time to time during the first five years of the term of this Convention to suspend altogether the taking of sealskins on such islands or shores subject to its jurisdiction, and to impose during the term of this Convention such restrictions and regulations upon the total number of skins to be taken in any season, and the manner and times and places of taking them as may seem necessary to preserve and protect the Russian seal herd or to increase its number; but it is agreed, nevertheless, on the part of Russia that during the last ten years of the term of this Convention not less than five per cent (5%) of the total number of seals on the Russian rookeries and hauling grounds will be killed annually, provided that said five per cent (5%) does not exceed eighty-five per cent (85%) of the three-year-old male seals hauling in such year.
>
> If, however, the total number of seals frequenting the Russian islands in any year falls below eighteen thousand (18,000) enumerated by official count, then the allowance of skins mentioned above and all killing of seals except such as may be necessary for the support of the natives on the islands may be suspended until the number of such seals again exceeds eighteen thousand (18,000) enumerated in like manner.

THE COMMANDER ISLANDS ROOKERIES IN 1911

While this treaty was being negotiated and signed in Washington and during the months following the signing things went from bad to worse on the Commander Islands, where two important rookeries literally became extinct.

On April 18, 1911, a council was held in St. Petersburg at the Department of Agriculture, at which the condition of the rookeries and the fur-seal industry as ascertained by Mr. Suvorof in 1910 was considered. As a consequence of the alarming report made by him it was decided to institute a closed season for the land killing of seals, to begin in 1912 and to remain in force 5 years. The reason for not starting the closed period at once was that, according to the contract with the Kamchatka company which expired in 1911, the latter was entitled to a quantity of sealskins, though the Government had reserved to itself the right to determine each year the number and kind of seals to be killed. The number of seals to be killed for skins was therefore set at 200, and as this would not furnish sufficient food for the natives, the latter were allowed to kill in addition 200 gray pups. Mr. Suvorof was also ordered to continue his examination of the condition of the seal herd during 1911.

Upon his arrival at the islands it was found that the rookeries had been still further depleted during the intervening winter by at least 30 per cent, according to his estimates, and that there were scarcely more than 200 bachelors present at any time on the hauling beaches. Moreover, even if that many could have been killed, to do so would have endangered the future supply of male life; hence, after consultation with the local administrator of the islands, he decided to allow the killing of 200 cows, 60 on Bering Island and 140 on Copper Island, in place of 200 bachelors.

The number of seals on the rookeries was now so small that he thought an approximate count could be easily made. It is probable that this is the most nearly correct estimate made of the Commander Islands herd at any time, though the number of pups is probably considerably (possibly 20 per cent) underestimated.

The tabulation of the count on all the rookeries follows:

Fur seals on Commander Islands rookeries in 1911

Rookery	Half bulls	Bulls	Cows	Black pups
COPPER ISLAND				
Glinka rookeries (July 22-25, new style):				
Gavarushetche			8	37
Sikatchinskoye	1	2	311	457
Zapalata	1	8	650	962
Palata		4	184	585
Zapadnoye		2	73	216
Urili and Peresheyek	7	15	1,101	1,078
Karabelnoye rookery (July 20, new style):				
Nerpitchi Kamen			20	15
Total	9	31	2,347	3,350
BERING ISLAND				
North rookery:				
Reef		4	1,150	891
Orlof Kamen			20	35
Sivutchi Kamen		2	159	338
Kishotchnoye				47
Total		6	1,329	1,311
Total (both islands)	9	37	[1] 3,676	4,661

[1] Suvorof (Viestnik Rybopromyshlennosti, Vol. 31, Sept., 1916, p. 446) gives 4,988 cows as the total for both islands.

In addition, there were counted on the various beaches 128 dead black pups and in the water off the rookeries about 415 cows. If, however, allowance is made for the probable number of black pups overlooked, the cows absent at sea feeding, the number of bachelors hauled out (220), and those at sea (including yearling males and females), the probability is that the Commander Islands herd in 1911 did not exceed 15,000 of both sexes and all ages.

By contrast it may here be noted that at the same time the Pribilof herd numbered about 125,000 seals all told, or eight times as many. During the prosperous days of the fur-seal industry, about 1880, the Commander Islands herd was nearly one-half that of the Pribilof Islands. Now, at the lowest ebb, the decline had been so entirely out of proportion that it was only one-eighth the size of the American herd. Nothing can better illustrate the disaster which had befallen the Russian herd. Even during this year of its extreme decline the factor that brought on the disaster was more active and destructive than ever before. The Japanese raiders and pelagic sealers, driven to desperation by the gradually diminishing catches, were growing more and more aggressive and reckless. It is necessary, in order to understand fully the causes of the continued decadence of the Commander Islands rookeries, to go into the history of the 1911 raids in some detail. The following account is therefore based on the story told by Mr. Suvorof, who, as stated above, was present on the islands that year.

Rookery raids in 1911.—From the table of the count on Copper Island (p. 315) it will be noted that no bulls or half bulls arrived in 1911 on Nerpitchi Kamen, the last remnant of the once big Karabelni rookeries. Immediately after the rookery guards had been withdrawn from this rookery in the fall of 1910 the seal pirates raided it, with the result that when Suvorof visited the place on July 20, 1911, he found only about 20 cows and 15 black pups; "of bulls there was not one." Five days later he returned and found not a single seal—"there was not even a carcass of a newborn pup." The pirates had apparently been there in the interval and literally cleaned out the rookery.

About the same time a raid on the Zapadni and Urili rookeries of the Glinka group was successfully carried out without attracting the attention of the rookery guards, for on July 21 they found there 80 cows killed and the carcasses of 121 black pups, and at Peresheyek the carcasses of 2 cows and 6 pups were picked up the next day. Here were also found, among other things, a Japanese oar, a double-barreled shotgun, a pair of binocles, a boat compass, skinning knives, cartridges, and ropes ready with slipknots for towing the seals killed. Evidently one of the pirate boats had been upset in the breakers. The raid must have taken place some time before, for the skins of some of the seals killed had already spoiled, and the birds had picked out the eyes of some.

A much more serious affair took place on July 21. During the evening of that day the guards noticed some Japanese schooners signaling to each other with flags. A concerted raid was therefore anticipated and reinforced guards were placed at different points along the coast. About midnight about 25 boats landed near the waterfall at Sikatchinskaya. Alarmed by the large number of men disembarked, the rookery guards fired several shots. Some of the raiding party then attempted, aided by the darkness, to sneak along the beach and to land near Palata but were met here by the fire of another squad of the rookery guards, so that they hurriedly went off to sea. One empty boat, however, was afterwards taken by the Aleut guards near the same beach. In the meantime another party hastened in the opposite direction but soon disappeared in the fog. At daybreak, however, a boat belonging to this party, in which were the corpses of two Japanese, was found at Babinskaya. Knowing that in the raiders' whaleboats there usually are three or four men, a search was made along the coast for the missing ones, and soon a live Japanese was taken on the beach near the rookery. During the whole of the following day a thick fog prevailed, out of which the firing of guns was heard, presumably the schooner summoning its boats. The captive Japanese was afterwards taken to Vladivostok for trial in order that an example might be established which would put a stop to the ever-increasing boldness of the raiders. The Russians believed that at this raid they killed about 14 raiders in addition to capturing the two boats.

Whether this repulse discouraged the pirates is not known, but the usual raids on the Bering rookery did not take place. However, the marauders for the first time landed on the southern shore of Bering Island. During the first half of July three natives of that island, who made a trip to Tolstoi Mys, noticed tracks of people who had piled up dry grass around the fox-hunting shelter hut at that place and set it on fire. The fire had gone out and the hut was spared.

While these events took place on shore the naval guard was kept even busier. At the request of the Department of Agriculture in St. Petersburg the Russian Navy Department detailed the gunboat *Manzhur* to do guard duty around the Commander Islands. In spite of adverse circumstances she probably averted further attacks on the rookeries and achieved considerable success in protecting the remnants of the seal herd by compelling the pirates to leave the islands earlier than usual. During the summer months the *Manzhur* made six trips to the islands, seized one schooner and three boats, examined a long line of schooners, and confiscated a quantity of skins. Nothing will better illustrate the methods of the pirates as well as their recklessness and boldness even in the face of the naval guard vessel than a detailed account of some of these occurrences.

During the second cruise to Copper Island the *Manzhur*, on June 26, seized the Japanese schooner *Kofudzi Maru* about 2½ miles from Sikatchinskaya Bukhta. A boat belonging to this schooner was captured at the same time about 2 miles from shore. On board the schooner there were found and confiscated 3 sea-otter skins (one perfectly fresh and with flesh still partly adhering) 6 salted fur-seal skins, 2 quite fresh, and 1 hair seal. The vessel was supplied with small 37-millimeter guns and military ammunition.

On its fourth cruise the commander of the *Manzhur* was informed of the raid and shooting that had taken place at the Glinka rookeries on July 21. On the 31st of that month he therefore proceeded to the strait between Copper and Bering Islands in search of Japanese schooners, hoping by an examination of their muster rolls to discover which ones had taken part in the nocturnal affair. The first to be examined was the *Chitose Maru No. 2* (*Dai-itchitose Maru*). Unfortunately a confrontation of the crew with the muster roll was impossible, since 8 of her 10 boats were hunting away out of sight at sea. However, one of the boats remaining on board as well as one arrested near by showed traces of having been hit by bullets, mute evidence of their having taken part in the shooting affair. An examination of the hold of the schooner revealed 59 skins of adult seals and 15 skins of black pups, some of them just turning gray, proof positive that they had been killed on the rookery, since the pups can not swim at that age. The skins were consequently confiscated, but the schooner itself was released, as the search was made outside the 3-mile Territorial zone.

The next schooner examined was the *Toei Maru*. All its boats were away, and in the hold were found only 3 adult skins and 2 black pups. The skins were seized but the schooner was released. The *Hashiman Maru* was next searched, but no skins found. All her boats were away. While the search was going on shots from the direction of the coast were heard on the *Manzhur*. Leaving the schooners at once and steaming toward Copper Island, three boats were met and seized within the 3-mile limit, not far from the Bobrovi Kamni at the northwest extremity of the island. The first of them, which belonged to the *Chitose No. 2*, contained no skins, but in the last two, belonging to the *Toei Maru*, 3 freshly killed seals with the skins still on were found. It was at once decided to seize both schooners, but these, observing the arrest of the boats, put on all sail in a hurry and were soon lost to sight. Nothing can better illustrate the hardihood of these raiders than the fact that they continued their depredations inside the Territorial limit with the Russian naval guard ship plainly on the horizon.

The *Manzhur* then turned toward Bering Island again and caught up with two more schooners. On the *Ivaki Maru* skins of 13 adults and 1 black pup were found, and on the *Kinkai Maru* 63 adult skins and 4 black pups. The skins were seized and the vessels released. On the *Konzen Maru* only 2 adult sealskins were found, and these were restored to the owner. On this schooner the log book proved to be in perfect order. However, on all the others the logs were found to be very carelessly kept, and the last two days not even written up.

On this trip the *Manzhur* searched 6 schooners, seized 3 boats with 10 Japanese sailors, and confiscated 3 sea-otter skins, 138 skins of adult seals, and 22 of black pups. As a result not more than 5 schooners were afterwards observed from Copper Island, and that a long distance off, while no more raids took place on shore that year. The schooners did not leave the neighborhood, however, for on August 24 the *Manzhur* boarded 3 vessels in the sea between the two islands, among them the same *Hashiman Maru* that had been searched three weeks before. As no black pups were found, and as it was impossible to prove that the adult skins had been taken inside the Territorial zone, no confiscation could be made.

Taking into consideration the vastness of the sea, the precipitous nature of the islands, the constant fogs and incessant storms, the impudent recklessness of the pirates, and the difficulty of chasing a fleet of small schooners in such dangerous, uncharted seas with a large naval vessel hundreds of miles from any harbor, it is small wonder that it has been almost impossible to protect the islands effectively.

PERIOD FROM 1912 TO 1917, THE 5-YEAR ZAPUSKA

With the treaty of 1911 going into effect and a 5-year Zapuska or closed season decreed, the Russian authorities began to hope for better times for the Commander Islands seals. At the end of the Zapuska in 1917 it was estimated, though without any particular pretense whatever at exactness, that the Commander Islands herd would number 40,000 seals, and that by 1926 it would be possible to take at least 18,000 to 20,000 bachelor skins. Unfortunately these expectations were entirely too roseate and could only lead to bitter disappointment.

The available material for a history of the Commander Islands fur-seal industry from 1912 to 1917 is rather scanty. The archives on Bering Island gave scarcely any information of value. Colonel Sokolnikof continued in charge of the administration during this period, but as he was generally at odds with the officials in the Department of Agriculture at St. Petersburg the latter relied chiefly on their own "specialists." Finally, in 1915, the fisheries and the fur industry were organized as a separate administration with headquarters at Copper Island, independent of the district official. In 1917 the department in St. Petersburg again sent Mr. Suvorof to the islands for the purpose of taking the necessary steps for the resumption of seal killing after the expiration of the five-year closed season.

These five years were on the whole quiet. The seals apparently were becoming more numerous. The increase in the number of bulls and males in general was particularly noticeable. Besides, raiders and pelagic sealers were not troubling the rookeries to any extent.

Unfortunately there is available no reliable or even approximately rational census of the increase. The treaty of 1911, it is true, assumes that an official count shall be made as a basis for all calculations regarding the permissible number of skins to be taken. Accordingly, instructions were given the local authorities to count the various classes of seals present on the rookeries at regular intervals throughout the season.

In all previous reports the writer has emphasized the physical difficulties in the way of a reliable count of the seals on the Commander Islands. The difficulties encountered on the Pribilof rookeries were multiplied and amplified enormously on the Russian islands, and, besides, there were no persons on the islands competent to make even an intelligent estimate. The count was placed in the hands of the native overseers of the rookery guards and the results are positively grotesque. There are available the certified official counts for Copper Island from 1915 to 1921, inclusive (except that of 1917, which was missing), and the counts for Bering Island during 1914 and 1915, which were extracted from the original documents in the archives on Bering Island. A glance at these figures demonstrates beyond question the above assertion. It would serve no useful purpose to set them forth in detail, but, considering the importance of establishing the facts once and for all, there are given below the tables for the year 1914 for Bering Island, 1915 for both islands, and 1916 for Copper Island.

Count of fur seals on Bering Island by rookery guards in 1914

Date	Bulls	Half bulls	Bachelors	Cows	Pups	Seen in the sea	Total
May 11	1						1
May 16	1						1
May 17	2						2
May 23	3			3		1	7
May 24	3			3		2	8
May 26	4	2		5			11
May 31	5	3		16		3	27
June 1	6	4		13		12	35
June 3	6	7		20	1	1	35
June 7	10	7		25	3	10	55
June 14	18	13	45	88	56	65	279
June 16	18	13	66	144	83	125	249
June 21	31	23	130	450	150	139	
June 28	32	20	132	880	340	150	
July 1	32	11	121	754	553	210	
July 5	32	11	133	994	623	180	
July 12	45	61	144	1,300	1,384	30	
July 16	45	61	152	1,340	1,384	70	
July 19	45	61	152	1,410	1,390	100	
July 26	45	61	150	1,455	1,433	200	
August 1	36	56	108	1,143	1,148	150	
August 9	27	38	330	1,977	1,713	1,415	
August 16	23	16	207	1,960	2,093	2,955	6,236
August 23	20	14	215	1,960	2,073	2,000	
August 30	14	13	200	1,545	1,690	1,600	
September 1	17	14	204	1,798	1,910	1,100	
September 6	15	13	173	1,995	2,000	1,100	
September 13	12	11	130	1,769	1,819	1,110	
September 15	11	11	110	1,665	1,720	1,800	
September 20	11	11	110	1,665	1,680	1,200	
September 27	8	7	40	809	1,033	1,500	
October 1	7	8	38	745	861	2,000	
October 4	5	2	10	1,069	1,360	700	
October 11	5	1		633	105	500	
October 16	1	1		85	58	130	
October 18				230	210	20	
October 25	2			104	50	1	

Count of fur seals on Bering Island by rookery guards in 1915

[No distinction made between harem bulls and idle bulls; yearlings not counted separately]

Date	Bulls	Half bulls	Bachelors	Cows	Pups	Seen in the sea	Total
May 1	1						1
May 9	1	1					2
May 15	3	1				2	6
May 16	3	1				4	8
May 20	6	1				8	15
May 23	10	5	1	5		4	25
May 30	16	5	1	13		1	36
June 1	23	6	6	17		5	57
June 4	28	9	8	20	1	3	69
June 6	25	9	9	25	5	9	82
June 13	26	17	18	63	28	16	168
June 15	28	18	25	79	40	27	217
June 20	29	20	42	140	82	80	393
June 27	74	20	127	1, 901	1, 071	30	3, 223
July 1	90	20	100	2, 241	1, 501	100	4, 052
July 4	93	27	100	2, 331	1, 521	200	4, 272
July 11	91	20	100	2, 201	1, 701	500	4, 613
July 18	99	30	100	2, 561	1, 600	300	4, 690
July 25	116	29	419	2, 989	1, 700	600	5, 853
August 1	92	28	130	2, 579	1, 700	300	4, 829
August 8	78	23	107	1, 428	1, 770	500	3, 406
August 10	80	48	149	1, 362	1, 193	600	3, 432
August 19	31	15	223	1, 266	1, 034	1, 800	4, 369
August 29	38	21	206	967	656	400	2, 088
September 4	37	25	170	918	880	341	2, 371
September 9	46	18	274	1, 078	770		2, 186
September 18	14	5		273	1, 319		1, 611
September 26	9	4	14	186	222	1, 800	2, 235
October 3				800		2, 000	2, 800
October 10				950		1, 400	2, 350
October 17	1			120	115	60	292
October 23				22	26	10	58
October 30				10	9	4	23
November 6							

Count of fur seals on Copper Island by rookery guards in 1915

[Schedule probably misunderstood; the figures under "Idle bulls" are probably intended for both harem and idle bulls]

Date	Harem bulls	Idle bulls	Half bulls	Bachelors	Cows	Pups	Yearlings	Seen in the sea	Total
May 17		4							4
May 21		5	2						7
May 28		9	3	4	1				17
June 8		34	13	36	1				84
June 14		71	33	78	1				183
June 18		81	37	149	1	1			169
June 25		117	71	361	74	38			662
June 27		117	75	546	123	65			926
July 7		170	137	882	778	482			2, 449
July 13		215	150	1, 168	3, 174	1, 671			6, 578
July 21		223	180	2, 858	4, 075	2, 549			9, 875
July 25		225	188	3, 617	5, 378	3, 206			12, 614
August 3		316	191	2, 163	6, 618	3, 891			13, 179
August 12		243	172	3, 760	5, 038	3, 990	60	760	14, 023
August 27		89	84	3, 154	1, 984	1, 626	183	1, 161	7, 501
August 31		218	160	3, 509	4, 732	2, 926	161	2, 318	14, 024
September 3		214	168	2, 822	4, 468	4, 647	158	2, 987	15, 464
September 14		305	206	1, 635	1, 778	1, 796	196	1, 750	7, 666
September 18		222	183	1, 666	3, 405	3, 207	200	570	9, 453
September 23		206	170	1, 165	3, 240	4, 186	178	658	9, 803
September 28		239	202	1, 282	4, 678	4, 630	156	750	11, 937
October 7		107	103	384	2, 860	3, 506	173	2, 785	9, 918
October 12		167	103	345	2, 797	2, 675	178	3, 250	9, 485
October 22		68	78	490	2, 622	2, 688	119	590	6, 655
October 28		41	49	311	2, 180	2, 400	62	902	5, 945
November 5		9	15	10	990	850	95	345	2, 314

Count of fur seals on Copper Island by rookery guards in 1916

Date	Harem bulls	Idle bulls	Half bulls	Bachelors	Cows	Pups	Yearlings	Seen in the sea	Total
May 5	-----	2	-----	-----	-----	-----	-----	-----	2
May 9	-----	1	1	6	-----	-----	-----	-----	8
May 23	-----	18	-----	42	-----	-----	-----	-----	60
May 29	-----	36	1	23	-----	-----	-----	-----	60
June 2	-----	63	6	52	-----	-----	-----	-----	121
June 16	-----	99	4	72	1	-----	2	7	185
June 29	-----	103	82	383	257	130	7	12	1,174
July 3	-----	358	91	322	672	376	13	58	1,890
July 16	-----	162	50	276	978	854	3	180	2,503
July 25	-----	164	33	188	595	657	16	147	1,800
August 4	-----	267	34	289	2,755	2,678	-----	1,710	7,733
August 15	-----	275	39	3,750	4,400	2,004	147	431	11,046
August 30	-----	214	163	1,136	2,600	2,324	398	846	7,681
September 7	-----	230	145	1,290	2,360	1,970	376	4,484	10,955
September 13	271	75	174	1,300	2,178	1,605	335	1,675	7,613
September 26	149	81	113	2,100	2,326	1,438	573	1,980	8,760
October 1	-----	190	135	1,002	2,500	2,358	191	1,715	8,091
October 10	-----	82	26	468	900	1,150	60	2,863	5,558
October 22	-----	140	118	1,316	1,900	1,220	67	1,348	6,110
November 5	-----	31	6	240	270	560	-----	719	1,826
November 14	-----	13	2	100	139	294	-----	133	681
November 17	-----	15	-----	15	19	15	-----	90	154
November 22	-----	5	2	5	6	3	-----	17	38
November 27	-----	-----	-----	-----	-----	-----	-----	4	4

Certain features of these extraordinary tables which otherwise might seem incomprehensible are explained hereafter.

In the Copper Island count it will be noted that the column designated "harem bulls" has been left blank. Evidently the official who made the count did not understand the difference between "harem bulls" and "idle bulls," hence the latter may be considered as including both categories. No such distinction was made in the Bering Island count. However, in 1916 the Copper Island census taker actually counted harem bulls on two dates. Thus we find enumerated on September 7 no harem bulls but 230 idle bulls; on September 13, 271 harem bulls and 75 idle bulls; on September 26, 149 harem bulls and 81 idle bulls; and on October 1, again, no harem bulls and 190 idle bulls. In 1918 he was evidently better instructed, for now we find harem bulls consistently enumerated from June 28 to September 2. In 1919, however, according to his figures, the harems lasted from July 2 to October 11, in 1920 from June 15 to August 30, and in 1921 from July 27 to August 30.

Another peculiarity of the Copper Island census is the detailed figures representing the seals counted in the sea off the rookeries. Thus the pretense of having counted 7,150 seals in the water on August 23, 1921, will be appreciated by anyone who has ever attempted a similar task. The Bering Island enumerator, on the other hand, shows better judgment in this respect, since his figures, when he deals with more than 30, are round number estimates up to 2,000, except on September 4, 1915, when he counted 341 in the sea.

Utterly hopeless as these enumerations are, at least one general conclusion may be reached, namely, that the bulls have been steadily increasing since 1911. The bulls form the only conspicuous class of seals that may be counted with some approximation to the actual number present. It is true that even in this regard the tables leave much to be desired; nevertheless, the fact of the increase can not well be doubted. From the Copper Island tables I have compiled the following significant figures:

Bulls present on Copper Island, 1915 to 1921 [1]

	1915	1916	1918	1919	1920	1921
Count between June 12 and 17	104	103	287	254	404	271
Maximum count (on various dates before Aug. 15)	507	449	682	572	643	822
Average of the counts in July (not including half bulls)	230	197	469	343	355	477

[1] Count for 1917 missing.

Remembering what has been said about the Copper Island census taker not understanding the difference between the categories of bulls, and without attempting to account for the glaring inconsistencies and the lack of an even approximately orderly increase, the significant fact remains that in 1911 a maximum of 40 bulls was counted on Copper Island. This figure, from its very smallness, can not have been far from the actual number. We may therefore safely conclude that the number of males engaged in reproduction increased from less than 50 in 1911 to not less than 250 in 1918 and 300 in 1921.

It must be admitted that the census of the Bering Island North Rookery is less fantastic than that of Copper Island. The maximum of bulls for 1914 and 1915—namely, 106 and 145, respectively—may not be much out of the way, and taken in connection with the fact that in 1911 there were said to be only 6 bulls on that rookery it is fully in agreement with the indications for Copper Island.

While a certain degree of credibility attaches to the estimates of bulls present on the rookeries, the same can not be claimed for the so-called count of cows and pups. The figures presented are nothing but wild guesses, and are only less fantastic than the figures presented for the seals counted at sea in front of the rookeries. The acme of absurdity is reached by the Copper Island census taker who, for instance, on August 13, 16, and 23, 1921, reports, respectively, 6,090, 7,162, and 7,150 seals sporting in the water off the Glinka rookeries.

KILLING RESUMED IN 1917

In 1917 the five-year closed season expired and the question of resuming killing and determining the quota of young bachelors to be killed was being taken up by the authorities in St. Petersburg. Mr. Suvorof, who made the last examination of the rookeries in 1911, was again sent to the Commander Islands for the purpose of looking into conditions on the rookeries and deciding these weighty questions accordingly.

It will be remembered that at the conclusion of the treaty in 1911, Mr. Suvorof, on the basis of a combined count and estimate of about 4,800 pups, made by himself, indulged in the hope that by 1917 the total herd might have grown to 40,000 seals of all ages. After a combined count and estimate, presumably made upon the same principles and according to the same methods employed by him in 1911 (see page 315), he came to the conclusion that in 1917 the total number of seals was about 13,500. Naturally he was disappointed. However, before concluding this discussion we believe it will be shown that on the one hand his expectation of 40,000 was too sanguine and on the other his estimate of the size of the herd, both in 1911 and in 1917, was too low.

As shown above, the great calamity of the Commander Islands during the years preceding 1911 was supposed to have been the disproportionate falling off of the bull element, which had reached such a low ebb that the Russians thought it necessary to slaughter cows by the thousands for the purpose of establishing the desired proportion between the sexes. It was with some satisfaction, therefore, that upon his return in 1917 Mr. Suvorof found this condition changed. It may be assumed that the count of the bulls is approximately correct—at least the number is probably not too low. He says that 572 bulls and 172 half bulls were counted, but that a number of bulls could not be counted on Lebiazhe and Babitche rookeries and that consequently the total was considerably higher. The number of harems given is 265, and the number of cows per harem about 18.8, but inasmuch as the uncounted bulls on the two rookeries were not included in the calculation the average harem was even smaller (though it is not explained how the pups could have been counted on rookeries where the bulls could not be counted). Bearing in mind that the average harem in 1911 was supposed to be over 96, this reduction to 18 or less in 1917 is certainly astonishing, especially if we compare it with what took place on the Pribilofs during the same period and under the same conditions, where, with a not unduly depleted bull stock in 1911, the average harem in 1917 had not been lowered below 26 cows.

The conclusion is therefore inescapable that if the number of bulls was even approximately correct that of the breeding cows was estimated too low. This is the more plausible because of the methods used in taking the census, as remarked before. Inevitably the number of pups was underestimated both in 1911 and in 1917. In the latter year for the first time Mr. Suvorof proceeded on the theory that the number of black pups on the rookeries is equivalent to the number of breeding cows. His figure for the two classes of seals for 1917 was 4,982. It would not be surprising if this were an undervaluation of 20 per cent.

While it is admitted that the estimates made by Mr. Suvorof in 1911 and 1917 are comparable with each other because they were made according to the same principles and methods, no value whatever can be attached to the figures given for each of the intermediate years based upon the enumerations made by the local authorities. The figures received in St. Petersburg during the years 1912 to 1916 (except 1915, for which none were submitted) are given by Suvorof in an article published in 1916 (Viestnik Rybopromyshlennosti, vol. 31, Sept., 1916, p. 446), as follows:

Comparison of figures received in St. Petersburg for Commander Islands seal herd

Class of seals	1912	1913	1914	1916
Bulls	37	64	249	533
Half bulls	19	74	255	252
Cows	5,329	5,240	4,983	3,326
Black pups	5,212	5,000	4,647	4,671
Bachelors	375	783	671	1,365
Seen in water				4,000
Total	10,972	11,161	[1] 10,775	[1] 14,169

[1] These figures are those given by Suvorof; the actual summation gives 10,805 and 14,147, respectively.

Just what relation these figures bear to the official counts, the absurdity of which has been demonstrated above, can not be stated, but no system of calculation or interpretation can possibly produce credible figures for those years. Mr. Suvorof, after his visit in 1917, submitted the following figures [11] for breeding females:

1911	4, 839	1914	4, 872
1912	5, 234	1916	4, 769
1913	4, 860	1917	4, 982

He thus came to the conclusion that while the male life had progressed satisfactorily, the number of females practically remained stationary, and he tried to explain this alleged fact by the curious assumption that pelagic sealing had caused a great surplus of superannuated cows, which, after pelagic sealing ceased, died off as fast as new ones were born; but he failed to explain how old cows would have a better chance to escape the pelagic sealers than young ones. The true explanation seems to be that the Russians reckoned with a lower mortality than experience has shown to occur. The whole history of the fur-seal industry of the Commander Islands seems to indicate that the normal mortality of the Russian herd during the migration season is even higher than that of the American herd; but if that is true, the expectation for 1917, based on Suvorof's own estimate of the living black pups in 1911, should not greatly exceed the number he reported having found in that year.[12]

The total number of seals present on the Commander Islands rookeries in 1917 according to his calculation was 13,267. It has already been said that his figures for 1911 probably were too low, and also that those given for 1917 are correspondingly low. This belief is based, first, on the conviction that the combination count-estimate of black pups, from the way it was undertaken, must have fallen considerably short of the actual number, and, second, on the fact that his calculations, at least those of 1911, did not take into consideration the number of seals that remain at sea during the whole season. With these probabilities in mind, we have indulged in the following speculation:

Assuming for 1911 an undervaluation of 10 per cent in the number of black pups alleged to have been on the Commander Islands rookeries at that time, viz, 4,661, we start with a round number of 5,100, and accepting the count of 46 bulls at its face value we would be justified in estimating the total number of seals of all the other classes to have been, in 1911, *including those absent at sea*, as follows:

Cows	5, 100
Black pups	5, 100
Bulls	46
Bachelors	1, 350
2-year-old females	1, 200
Yearling females	1, 275
Yearling males	1, 275
Total	15, 346

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[11] These figures differ somewhat from his tabulation given above.

[12] His own estimate in 1916 as to how many might be expected in 1917 was 5,830 cows (Viestnik Rybopromyshlennoski, vol. 31, 1916, p. 448).

Assuming again a mortality equal to that believed to occur in the Pribilof herd, the Commander Islands herd in 1917 should have been composed somewhat as follows:

Cows	6, 640
Black pups	6, 640
Bulls (harem, surplus, and idle)	800
Bachelors	5, 708
2-year-old females	1, 609
Yearling females	2, 066
Yearling males	2, 052
Total	25, 515

Mr. Suvorof's figures for 1917 are as follows:

Cows	4, 982
Pups	4, 982
Bulls (harem, surplus, and idle) over	744
Bachelors	2, 559

It will be noted that he left out the yearlings, which, according to my figures, should have amounted to 4,118, as well as the 2-year virgins, 1,609, a total of 5,727 seals not accounted for. Presumably the 2,559 bachelors enumerated are those supposed to be seen on or about the rookeries without accounting for those absent on the feeding grounds. Suvorof expressly stated that the number of seals on all the rookeries in 1917 was about 13,267, and that the total number in the Commander Islands herd was 16,957. With the above explanation it will be seen that there is less discrepancy between the figures than is apparent at first glance. At any rate, it seems certain that the number of seals of all classes present on the rookeries, including pups, yearlings, and 2-year-old females, did not exceed 18,000.

The question now presented itself as to the number of seals to be killed in 1917. As already noted, Article XII of the fur-seal treaty stipulates that during the last 10 years of that convention not less than 5 per cent of the total number of seals on the Russian rookeries and hauling grounds will be killed annually, provided that said 5 per cent does not exceed 85 per cent of the 3-year-old male seals hauling in such year.

Suvorof's figures indicate that at least 2,559 bachelors hauled out during that year, but apparently he did not ascertain the relative number of the various year classes, which would, in fact, have been an impossible task. It is thought, however, that no matter what figures we accept for the total the number of 3-year-old males hauled out did not exceed 700. The Russians would consequently not have been required to kill more than 600 seals all told; but that article of the treaty provides further that if the total number of seals frequenting the Russian islands in any year falls below 18,000, as enumerated by official count, killing may be suspended. It is taken for granted that by "frequenting" the treaty means hauling ashore, for surely nobody, not even an official count, can enumerate the thousands of seals remaining hundreds of miles away at sea without going ashore. As stated above, it is almost certain that even under the highest estimate the number of seals hauling out on the Commander Islands in 1917 did not exceed 18,000. Nevertheless, the Russians decided to proceed with the killing. Mr. Suvorof gives the following result:

Seals killed on the Commander Islands in 1917

Classes	Bering Island [1]	Copper Island	Total
3-year-old males	296	238	534
4-year-old males	4	211	215
Half bulls		35	35
Bulls		17	17
Cows	6	3	9
Total	306	504	810

[1] From the "akts" in the Bering Island archives the seals on that island were chiefly taken in three drives: July 18, 60; July 25, 152; and Aug. 3, 88 seals.

The few females were killed accidentally or because they were "sickly," and the bulls and half bulls to reduce the dangerous excess of these classes.

The latter fact is the most eloquent demonstration of the value of the treaty in protecting the Commander Islands seals against pelagic sealing. The amazing reduction of bulls before 1911, which even served the Russians as an excuse for the desperate expedient of the wholesale killing of breeding females, was not only overcome, but it was even found necessary to kill off some of the superfluous adult males to protect the cows and pups against the dangers resulting from the crowding and fighting of the bulls.

In order to complete as far as possible the history of the sealing in 1917, the following details relating to the drives on North Rookery are given:

Weight of skins taken in drive on North Rookery, Bering Island, July 18, 1917

Class	Weight in pounds	Number of skins	Class	Weight in pounds	Number of skins
Bachelors	5¾	1	Bachelors	8¼	1
Do	6	1	Do	8½	6
Do	6¼	1	Do	8¾	2
Do	6½	4	Do	9	3
Do	6¾	6	Do	9¼	2
Do	7	7	Do	9½	2
Do	7¼	9	Do	9¾	1
Do	7½	3	Cows	10½	1
Do	7¾	7			
Do	8	3	Total		6

Count of seals on North Rookery, Bering Island, July 18, 1917

Class of seals	Reef	Hauling ground	Mali Sivutchi Kamen	Bolshoi Sivutchi Kamen	In water or on outlying rocks	Total
Bulls	96	13		29		138
Half bulls	20	42		2		64
Bachelors	15	379	5?	3		402
Cows	1,031		?	191		1,222
Black pups	1,157			2		1,159
Dead black pups	65			3		68
Bachelors and cows					87	87
Total	2,384	434	5	230	87	[1] 3,140

[1] Of these, 59 bachelors and 1 cow were killed, as shown in preceding table, and 25 3-year-old bachelors were branded on the shoulder with the figure 7.

On July 25, 1917, there was another drive on North Rookery, Bering Island, in which 152 bachelors were killed. On the succeeding day the following count was made:

Count of seals on North Rookery, Bering Island, July 26, 1917

Class of seals	Reef	Sivutchi Kamen	In water or on outlying rocks	Total
Bulls	110	14		124
Half bulls	39	1		40
Bachelors	171	2		173
Cows	1,317	99		1,416
Black pups	1,161	216		1,377
Dead black pups	30	5		35
Bachelors and cows			210	210
Total	2,828	337	210	3,375

On the same rookery a drive on August 3, 1917, yielded 87 bachelor skins, minimum weight 6 pounds, maximum weight 9¼ pounds, and 1 cow skin weighing 6 pounds.

THE COMMANDER ISLANDS AFTER 1917

While the somewhat exaggerated expectations were not realized, nevertheless there had been noticeable progress, and the outlook for the future was undoubtedly promising. Commercial killing had been resumed and with proper management from then on should have become a steadily increasing source of revenue. The total of 810 skins taken was obtained from those age categories of seals that were practically nonexistent five years before. In 1911 in order to obtain 200 skins it was necessary to kill 200 cows; in 1917 four times as many young bachelors were killed without difficulty, and not only with no danger to the future welfare of the herd but to its decided advantage. Evidently the restoration of the Commander Islands fur-seal herd was only a question of time. Unforeseen complications, however, intervened to the great detriment of the herd.

With the Russian revolution of March 15, 1917, a new chapter in the history of the seal herd was inaugurated. The immediate result on the islands was the retirement of the old officers. In 1920, after the Bolshevik Soviet Republic had taken over the Russian Government, Pietr Aleksandrovitch Khramof, as the head agent for the fisheries and sealing industry, was sent to the islands. He arrived at Bering Island on September 6 and afterward made his headquarters on Copper Island. He was young, enthusiastic, and energetic, but without experience.

On October 24, 1920, two Bolshevik representatives of the Communist Government of Kamchatka in Petropaulski arrived. They stayed on Bering Island long enough to organize a Communist Government and then departed.

In the spring of 1921 two representatives of the Soviet of the Eastern Republic were landed at the islands. To them the natives of Bering Island delivered the furs taken during the winter of 1920–21, to be converted into supplies of various kinds. According to the official receipt issued to the fisheries agent on May 27, 1921, the following furs were taken: 614 good blue fox skins, 2 damaged blue and 6 white fox skins, besides 4 whole skins and 1 damaged skin of gray fur-seal pups and 1 skin from a full-grown seal found dead.

In the meantime the Soviet Government in Vladivostok had been superseded by a "white" one and plans were laid for the supression of the Kamchatkan Federal Republic in Petropaulski. The "white" government in Vladivostok was in turn overthrown by the forces of the "Chita Government," or the so-called Far Eastern Republic, during October, 1922. Shortly afterwards the Petropaulski Government was also deposed and the whole Coast Province, including Kamchatka and the Commander Islands, was again in the hands of the "red" or Soviet Republic.

The details as to what took place on the Commander Islands since 1917 have been set forth in order that the conditions on the Russian fur-seal islands during this highly critical period, when the seal herd needed the most careful nursing, may be fully understood. As will be seen, it was mainly a period of instability and lack of authority and discipline. The natives had been taught not to pay any attention to the orders of the officials, and naturally all law and regulation practically ceased. That under such circumstances complete chaos did not ensue speaks well for the common sense of the natives, yet it was but natural that the seal herd should suffer much as it did during the "interregnum" from 1868 to 1871 (Asiatic Fur Seal Islands, p. 117). Alcohol now, as then, played an important role. The natives, unrestrained by the strong arm of the Russian officials, would sacrifice anything for the chance to get drunk. With the many vessels of varying allegiance—Japanese and "white" and "red" Russians—touching at the islands, there was no lack of supply, and the means of obtaining the much desired alcohol were the furs of seals, foxes, and sea otters surreptitiously killed and secretly stored away. The number of fur-seal skins disposed of in this way by the natives may not have been very great because of their bulk and the difficulties connected with curing them, but there is reason to believe that in 1919, 1920, and early 1921 there were shipped fur-seal skins in considerable quantity of which no official records were kept.

Of course, all these transactions being illegal, it was next to impossible to obtain definite and reliable data. Even the crews of the Japanese men-of-war that visited the islands several times each year were reported to trade extensively with the natives, obtaining furs in exchange for liquor and old clothes. Copies of official reports to that effect were furnished the writer.

With the practical abandonment of the naval seal patrol by the Russians after the revolution, the seal pirates began their destructive work again, but while before the treaty of 1911 it was lawful for them to sell their skins in the markets of at least three of the contracting powers, they were now compelled to dispose of their illegal catches surreptitiously. Consequently, while formerly it was possible to demonstrate by figures the pelagic losses of the seal herd, it is now only a matter of conjecture how many skins were taken at sea and in raids on the rookeries. If it be recalled with what boldness the seal pirates operated about the islands in 1911 (see pages 316 to 318) almost in the presence of the Russian men-of-war, it may easily be understood that during the critical years of the revolution and after, when no naval authority was there to check them, their activities and recklessness increased from year to year.

Schooners were hovering around the islands and were sighted from time to time by the natives when the fog lifted long enough to afford a clear view of the ocean, but as to their catches nothing definite is known. It was only when the crews attempted raiding the seals on shore and were discovered in the act by the rookery guards that tangible facts became available. Thus in 1921 North Rookery, on Bering Island, was raided. The schooner escaped, but five Japanese sealers were caught on shore, and were afterwards taken off by a Japanese transport and presumably taken to Japan and given a trial according to the treaty.

In 1922 no less than four schooners were observed hanging around the rookeries. On July 11 a Japanese schooner anchored off the seal rookery on Copper Island and sent a boat ashore with five armed men who started killing seals. The native rookery guards, who had been watching the performance from behind the rocks, suddenly descended on the beach and seized the boat, at the same time firing at the landing party, who ran away. The natives also shot at the schooner, which was compelled to weigh anchor and disappear, leaving the captain and the owner, as well as the senior machinist, behind. They, with two sailors, surrendered to the guards the next day and were taken to the main village of the island, where they were locked up by the fisheries agent.

Less than two weeks after this affair another schooner anchored off the rookery near the southeastern end of the island less than 300 feet from shore and was caught, together with the captain, the owner, and the entire crew, 14 men altogether. On board the schooner were found 96 fresh sealskins and 5 live blue foxes, which it was stated had been caught on Bering Island where the schooner's men had also been ashore.

It is not even necessary to give credence to the assertion that the natives had on occasion accepted whisky from the raiders in return for permission to kill seals in order to understand that with the lawlessness and the loosening of all obligations which followed the revolution, as set forth above, the slow but sure increase of the seal herd up to 1917 met with a decided check, so great in fact that orders were given in 1921 immediately to stop all official killing of seals on land. A report at that time represented the exact number of seals on the Bering Island rookery as being 4,339, including the newborn. On Copper Island the day of inspection was very warm and besides it was very late in the season after the harems had broken up, hence only an approximate estimate could be made, the total number of seals there being estimated at 6,000. As the total for both islands consequently fell far below the 18,000 stipulated in the treaty prohibiting further killing seemed justified.

The writer was assured the Bering Island census of 1921 had been made "head by head," and that it was not a mere estimate. It was taken on August 16, 1921, and the detailed figures follow:

Old bulls	48
Young bulls	60
Half bulls	56
Bachelors	418
Cows	2, 221
Black pups	1, 438
Yearlings	98
Total	4, 339

Experts will know how to value this "count," and the writer calls attention merely to the curious proportion of cows and black pups, there being nearly half more of the former than of the latter, a feature that characterizes so many of the Russian estimates.

How the estimate of 6,000 seals for Copper Island was arrived at is not known, but it was certainly not based upon the periodical count of the rookery guards, which for August 16, the same date as the above Bering Island count, gave the following figures:

Harem bulls	118
Bulls without harems	264
Half bulls	220
Bachelors	1, 381
Cows	2, 680
Black pups	2, 200
Yearlings	80
In the water	7, 162
Total	14, 105

Counting the 7,162 seals in the water must be regarded as an astonishing performance, but does not inspire great confidence in the accuracy of the rest of the count. However, disregarding these fantastic figures, in view of the status of the rookeries as the writer found them in 1922 we have no hesitation in accepting the statement that in 1921 there were less than 18,000 seals frequenting the rookeries and that there was ample justification for stopping the killing of seals for skins.

NUMBER OF SEALS KILLED ON THE COMMANDER ISLANDS BETWEEN 1917 AND 1922

Unfortunately complete official returns as to the number of skins taken since land killing was resumed in 1917 until it was again stopped in 1921 have not been available. The writer has seen only Mr. Suvorof's figures for 1917, as given above, embracing the killings on both islands, amounting to 810 skins. In the Bering Island archives were found reports of killings on that island only for 1918 and 1919, and with regard to these it is not certain that they are complete. For 1920 we know of no record except a statement said to have been taken from "A report published by the special delegation of the Far Eastern Siberian Republic to the Washington Conference, 1922," to the effect that the production of fur-seal skins on the Commander Islands during 1920 was 1,000, probably only an approximate figure, which may or may not include 813 skins shipped by A. S. Yakum in the *Admiral Zavoiko* in May, 1921, as the *Magnit* took 400 skins away from Bering Island on September 9, 1920. On Bering Island in 1920 the natives were given permission to kill 100 seals, but they killed 400. These were the skins shipped on the *Magnit*. The *Yana*, in October, 1920, took the skins of 73 half bulls and 6 bachelors, and in Petropaulski we were informed that the sailors of the *Yana* brought "a lot of dried sealskins." It was also said that 52 skins were landed there is 1921 from the *Kamchatka Maru*.

On Bering Island the following killings were made in 1918: July 16, 115 bachelors, and July 24, 187 bachelors and 1 half bull, a total of 303 skins; and in 1919: July 3, 107 bachelors, and July 7, 68 bachelors, a total of 175. In 1921, 66 seals were killed July 7 on Bering Island for food and leather for the natives, and 32 seals were killed for the same purposes on Copper Island.

When the writer left the Commander Islands on August 8, 1922, no seals had been killed officially, nor was there any evidence in the Bering Island salt house that any skins had been salted, and the natives complained bitterly over the lack of fresh meat. We were informed shortly afterwards that a killing of 500 seals on both islands for food would be permitted later. The killing of over 2,700 seals is thus accounted for. To this number about 1,000 probably should be added for Copper Island during 1918 and 1919.

CONCLUSIONS

Taking all the above facts into consideration, there should be no surprise over the fact that the Commander Islands seal herd has not recuperated as rapidly as has the Pribilof herd. The writer's dismay at the sight of North Rookery on Bering Island on July 28, 1922, was primarily due to the fact that it had not been seen since 1897 and no information giving an adequate idea of the conditions as they existed in 1911, the year of the seal treaty, had been received. It was, of course, known to me in a general way that the herd was then in a serious state, and even that females had been killed, but nothing had reached Washington to make one realize the full extent of the disaster. Furthermore, the complete story of the depredations that have taken place since 1917, the number of seals killed on land and at sea during those years of lawlessness, and the lack of authoritative control on all sides probably never will be known; but allowing for all this, there seems to be a further circumstance which may have had a baneful influence in retarding or even checking the rehabilitation of the Commander Islands rookeries.

The northward movement of the two seal herds in the spring along the American and the Japanese coasts, respectively, is approximately alike on both sides. However, as has been pointed out heretofore,[13] the Commander Islands seals off the Japanese coast in the spring congregate in relatively greater masses and for a longer time in certain limited areas, a circumstance that makes them much more susceptible to close offshore attack.

At the beginning of May the seals commence to crowd the Gulf of Mororan, between Hondo and Yezo, and for nearly three weeks they are assembled here, during which time the heaviest damage is done to the herd. Toward the end of May the seals move northeastward along the coast of Yezo, comparatively near land, making a last stand to the east of Iturup about the middle of June.

The islands of Yezo and Iturup are the home of the Ainos, the aborigines of this region. Now, Article IV of the treaty of July 7, 1911, provides as follows:

> It is further agreed that the provisions of this Convention shall not apply to Indians, Ainos, Aleuts, or other aborigines dwelling on the coast of the waters mentioned in Article I, who carry on pelagic sealing in canoes not transported by or used in connection with other vessels, and propelled entirely by oars, paddles, or sails, and manned by not more than five persons each, in the way hitherto practiced and without the use of firearms; provided that such aborigines are not in the employment of other persons, or under contract to deliver the skins to any person.

In practice this article is probably the easiest to evade in the whole treaty. It has been found so on the American side. Effective control is very difficult, and there is a strong suspicion that every provision of the article is being violated.

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[13] Asiatic Fur-Seal Islands, p. 263 and Pl. 113.

Dr. G. Dallas Hanna says,[14] referring to this question, that dispatches in the daily press indicate that the figures as to the number of fur seals killed at sea under the treaty provisions are assuming proportions little short of alarming. Of course, official information as to the illegal killing and disposal of the skins can not be obtained, but the loss to the herd, especially as such a large percentage of the seals thus killed undoubtedly consists of gravid females, can readily be appreciated. If conditions are thus unsatisfactory on the American side there is no reason to believe that they are better on the Asiatic side, since in view of the peculiar bunching of the seals there, as stated above, the losses are probably proportionately greater. If there is ground for believing that the mainstay class of the Pribilof herd has been reduced in a single season by over 1 per cent,[15] the losses to the Commander Islands herd presumably exceed that figure considerably. The future prospects for the Russian fur-seal herd are thus less bright than for the American herd. The annual mortality is almost certainly greater, hence the recuperative power of the herd is correspondingly less.

This condition can be remedied only by a more effective control at sea according to Article VII of the treaty, both during the spring migration and the breeding season of the seals, as well as by a strict enforcement of Article IV. With regard to the latter, the only rational remedy would be the revocation of the privilege of the aborigines to take seals at sea, as suggested by Dr. Hanna.

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[14] Report of U. S. Commissioner of Fisheries, 1921 (1922), Appendix VI, p. 110.

[15] Hanna, op. cit.

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